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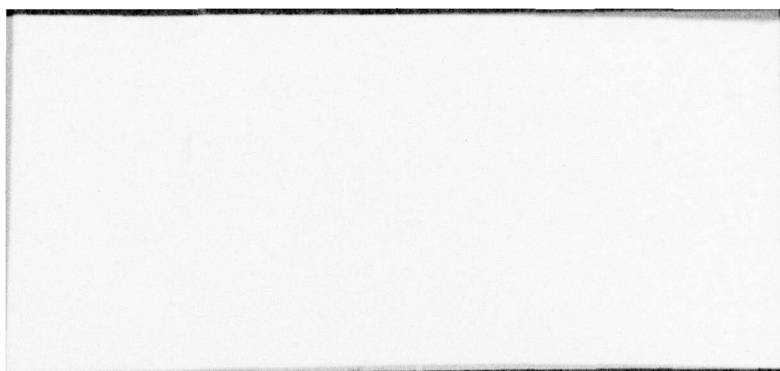
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N00173-77-C-0236

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6 INFRARED SEARCH AND TRACK  
EVALUATION MODEL (IRSTEM)

9 FINAL REPORT

14 SAI-A64-995-199

10 L. N. Peckham  
L. L. Doran

11 August 1978

12 196p.

Submitted to:

Electro-Optical Technology Program Office  
Naval Research Laboratory  
Washington, D. C. 20375

15 Contract N00173-77-C-0236

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Dr. Richard Steinberg  
Electro-Optical Technology  
Program Office  
Naval Research Laboratory  
Washington, D.C. 20375

Reference: Contract No. N00173-77-C-0236

Dear Dr. Steinberg:

Enclosed is the Final Report for Contract No. N00173-77-C-0236, Infrared Search and Track Evaluation Model (IRSTEM). This report, which documents the code development and includes a sample listing of IRSTEM, also incorporates your comments about the 15 August draft version.

Since the original contract has been recently modified, this report does not signify the completion of the contract but rather completion of only the original contract requirements. If you have any questions, please feel free to phone me at 505-265-7658.

Sincerely,

SCIENCE APPLICATIONS, INCORPORATED

Lawrence N. Peckham  
Principal Investigator

Copies: NRL Code 4100 (one copy)  
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## FOREWORD

✓ This report is the final report covering work performed for the Electro-Optical Technology Program Office at the Naval Research Laboratory under Contract N00173-77-C-0236. The purpose of this contract is to develop a system-level computer code to evaluate the performance of Infrared Search and Track systems. The Infrared Search and Track System Evaluation Model (IRSTEM) resulting from this contract is a deterministic code which models the background scene, atmospheric effects, sensor design characteristics and allows flexibility of incorporating a variety of signal processing options.

↪ This report summarizes the work documented in the three quarterly reports submitted under this contract and provides a summary of the theory behind the models used in IRSTEM, a program summary and a user's manual with sample programs. ↪ The authors wish to express their appreciation to Dr. Richard Steinberg, the Program Monitor, for his assistance in structuring and critiquing the code. We also wish to acknowledge the contributions of Dr. Frank Horrigan in establishing the initial code methodology, and the work of Mr. Paul Eitner and Dr. Robert Turner for the background and cloud radiance data, respectively. Similarly, we acknowledge the help of Mr. Fred Smith with the target signature data, and Mr. Jim Giles and Dr. James Griggs for their overall review and critique.

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# LIST OF SYMBOLS

Theory	Program	Theory Units	Description
$A_{BKG}$	-	$cm^2$	Area of background pixel
$A_d$	-	$m^2$	Detector area = $L_x L_y$
$A_E$	$A_E$	$cm^2$	Projected area of tailpipe
$A_G$	-	$cm^2$	Glint area ( $2500 cm^2$ )
$A_N$	$A_N$	$cm^2$	Projected area of missile nose
$A_S$	$A_S$	$cm^2$	Projected area of missile fuselage
$A_T$	$A_T$	$m^2$	Projected area of the target
$C_1$	$C_1$	$w \mu m^4 / cm^2$	Blackbody constant = $3.713 \times 10^4$
$C_2$	$C_2$	$\mu m - ^0K$	Blackbody constant = $1.4388 \times 10^4$
D	D	m	Optics diameter
$D^*$	DSTRPK	$cm \text{ } hz^{\frac{1}{2}} w^{-1}$	Detectivity
Dec	DEC	radians	Declination of sun
$D_T$	DT	m	Missile Diameter
d	-	-	Detector response function
F	FL	m	Focal Length
FFT	-	-	Fast Fourier Transform
FOV	-	-	Field-of-View
$f_o$	FO	hz	Electronics cutoff frequency
$f_p$	FUNC	-	Aspect dependence of the plume emission
$H_{Det}$	HDET	-	Detector transfer function
$H_{Elec}$	HELECT	-	Electronics transfer function
$H_{Opt}$	OTF	-	Optical transfer function
$H_S$	SR	$w/cm^2$	Solar irradiance at the reflecting surface
$H_T$	-	$w/cm^2$	Target irradiance
$h_E$	-	--	Electronics response function
IFOV	-	sr	Instantaneous field-of-view

# LIST OF SYMBOLS (Continued)

Theory	Program	Theory Units	
$I_{\max}$	IMAX	-	Number of pixels in vertical direction
$J_{\max}$	JMAX	-	Number of pixels in horizontal direction
$J_p$	TJP	w/sr/ $\mu$ m	Plume spectral radiant intensity
$J_t$	TJ	w/sr/ $\mu$ m	Total target spectral radiant intensity
$\vec{k}$	-	-	Spatial frequency transform vector = $\hat{i}k_x + \hat{j}k_y$
L	TL	m	Missile Length
Lat	RLAT	degrees	Latitude of engagement
Lha	LHA	degrees	Local hour angle of sun
$L_x$	DX	m	Detector dimension in scan direction
$L_y$	DY	m	Detector dimension orthogonal to scan direction
N	INL	mw/sr/cm <sup>2</sup> / $\mu$ m	Number of detectors fully within scene (INL) or radiance (mw/sr/cm <sup>2</sup> / $\mu$ m)
N*	-	w/sr/cm <sup>2</sup> / $\mu$ m	Blackbody spectral radiance.
$N_A$	APR	mw/cm <sup>2</sup> /sr/ $\mu$ m	Path radiance
$N_C$	-	mw/cm <sup>2</sup> /sr/ $\mu$ m	Cloud radiance
OVL	OVL	m	Detector overlap
PSF	-	-	Point-spread function of optical system
$R_d$	RD	v/w	Detector responsivity
$R_g$	RGLNT	m	Range to glint point
$R_L$	-	ohms	Load resistor
RN	RN	-	Random number
$\vec{r}$	-	-	Positional Vector
T	-	<sup>o</sup> K or w/cm <sup>2</sup>	Temperature or threshold irradiance
$T_E$	TE	<sup>o</sup> K	Temperature of tailpipe
$T_N$	TN	<sup>o</sup> K	Temperature of missile nose

# LIST OF SYMBOLS (Continued)

Theory	Program	Theory Units	Description
$T_S$	TF or TS	sec or $^{\circ}\text{K}$	Frame time or temperature of missile fuselage
$t$	T	sec	Time
$V_{\text{eff}}$	EFF	v	Voltage response with PSF added to $V_{\text{ideal}}$
$V_g$	VGLNT	v	Signal due to sunlint
$V_{\text{ideal}}$	VEFF	v	Voltage response before spatial effects are included
$V_n$	EFF	v	Voltage response from the electronics
$\hat{V}_n$	VNOISE	v	RMS level of system noise
$V'_n$	EFF	v	Voltage response from detector or from the electronics after random noise is added
$V_S$	VS	m/sec	Scan velocity in focal plane
$W$	BLKBDY	$\text{w}/\text{cm}^2/\mu\text{m}$	Blackbody emittance
$y$	Y	m	Vertical scene size in focal plane
$z_f$	YI	m	Center of $i_{\text{co}}$ detector
$\delta$	-	sr	Delta function or detector IFOV
$\Delta\lambda$	DV	$\mu\text{m}$	Integration interval for passband
$\Delta\nu$	CV	$\text{cm}^{-1}$	Integration intervals for passband
$\epsilon_B$	EB	-	Background emissivity
$\epsilon_N$	ETN	-	Emissivity of missile nose
$\epsilon_S$	ETS	-	Emissivity of missile fuselage
$\theta$	TH	rad	View angle of observer from cloud normal
$\theta'$	TH	rad	Supplement view angle
$\theta_{\text{ALT}}$	ALT	rad	Elevation angle of sun
$\theta_D$	-	rad	Solar dispersion angle off of a glint point (= 9.3 mr)
$\theta_E$	ELVS	rad	Zenith angle for the line-of-sight from the observer to the background cell
$\theta_L$	THL	rad	Zenith angle of observer as seen from cloud



# LIST OF SYMBOLS (Continued)

Theory	Program	Theory Units	Description
$\theta_0$	THO	rad	Solar zenith angle measured wrt cloud normal
$\theta_n$	THN	rad	Zenith angle of cloud normal
$\theta_s$	-	rad	Solar zenith angle
$\theta_{TS}$	THTATS	rad	Starting zenith angle of target
$\lambda$	XL	$\mu\text{m}$	Wavelength
$\bar{\lambda}$	-	$\mu\text{m}$	Mean wavelength for passband of interest
$\lambda_L$	XLAML	$\mu\text{m}$	Lower bound of passband
$\lambda_u$	XLAMU	$\mu\text{m}$	Upper bound of passband
$\nu_L$	BL	$\text{cm}^{-1}$	Lower bound of passband
$\nu_u$	BU	$\text{cm}^{-1}$	Upper bound of passband
$\epsilon$	ASPECT	degree	Aspect angle or view angle of missile
$\rho$	-	-	Direction vector in focal plane, $\hat{i}x + \hat{j}y$
$\rho_D$	RHO	-	Diffuse solar reflectivity
$\rho_G$	-	-	Specular reflectivity
$\sigma$	-	v or w/cm <sup>2</sup>	Noise level standard deviation
$\tau_A$	TAUA	-	Atmospheric transmission
$\tau_O$	TAUO	-	Transmission of optics
$\tau_p$	TGTAU	-	Plume transmission
$\phi$	PH	rad	Azimuth angle between sun and observer in plane of cloud (the smaller angle measured from the reciprocal of the sun's projection in the cloud's plane)
$\phi_L$	PHL	rad	True bearing of observer as seen from cloud
$\phi_n$	PHN	rad	True bearing of cloud normal

# LIST OF SYMBOLS (Continued)

<u>Theory</u>	<u>Program</u>	<u>Theory Units</u>	<u>Description</u>
$\phi_s$	TRUEB	rad	True bearing of sun (TRUEB in SUNLOC)
$\phi_{TB}$	PHL	rad	True bearing of background centroid
$\phi_{TS}$	PHITS	rad	Starting azimuth angle of target
$\Omega_c$	-	sr	Solid angle subtended by aperture, $\frac{\pi D^2}{4R^2}$
$\omega$	-	-	Transform frequency

## SECTION 1

### INTRODUCTION

Wide field-of-view Infrared Search and Track (IRST) systems are designed to search the engagement space and detect incoming threats based on the IR signatures generated by the exhaust plume or aerodynamically heated structure (see Figure 1). These systems complement RF radar because they are passive and because they operate in a different portion of the electromagnetic spectrum which makes it difficult to jam both the radar and the surveillance sensor simultaneously. On the other hand, one of the primary limitations of the IR surveillance sensor is its ability to detect targets at long ranges without excessive false alarms due to background clutter. There are a variety of options available to minimize the false alarms and increase the probability of detection including judicious selection of the spectrum bands, focal plane arrays and signal processing. The large number of options make it impractical to experimentally determine the optimal design, but there has been a general lack of analysis tools available to complement the experimental programs.

The purpose of the IRST evaluation model (IRSTEM) is to provide the analyst with a flexible tool for determining the performance of wide field-of-view surveillance sensors under realistic battlefield conditions. Flexibility is provided by allowing the user to specify the sensor characteristics including both the hardware design and software logic. Realism is provided by allowing the user to input a spatially and spectrally varying background scene which can include clouds, sun glints and other potential false targets. The ability of the search set to then detect the target can be analyzed using the user's specified hardware and signal processing since the code predicts the time-dependent signals from the individual detector preamplifiers.

IRST performance analyses generally are made assuming the background noise is Gaussian (in magnitude) and white (in frequency). These assumptions greatly simplify the computations and reduce the probability of detection ( $P_d$ ) and false alarm rate (FAR) computations to analytical expressions:



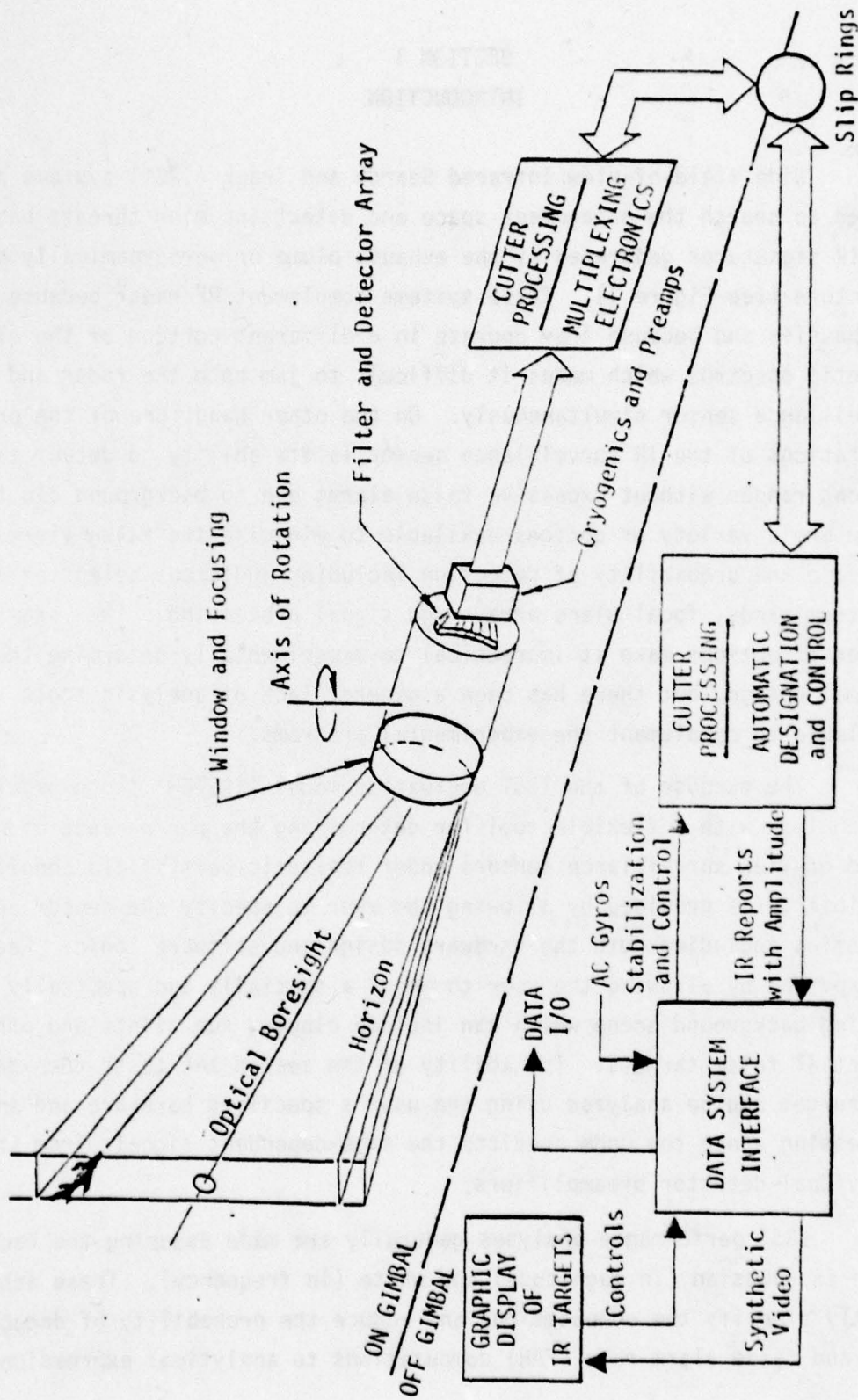


Figure 1. IRST Schematic.

$$P_d = \frac{1}{\sqrt{2\pi}\sigma_n} \int_T^{\infty} e^{-\frac{(H - H_T)^2}{2\sigma_n^2}} dH \quad (1)$$

and

$$FAR = \frac{1}{\sqrt{S}} \left[ \frac{f_2^3 - f_1^3}{f_2^2 - f_1^2} \right]^{1/2} e^{-T/2\sigma_n^2} \quad (2)$$

where

$H_T$  = irradiance of target at the aperture ( $w/cm^2$ )

$T$  = threshold level for clutter rejection ( $w/cm^2$ )

=  $S/N \cdot NEI$

$f_1, f_2$  = lower and upper video cutoff frequencies, respectively (hz)

$\sigma_n$  = standard deviation of background or system noise ( $w/cm^2$ )

If one wishes to incorporate the impact of spatial frequency variations on system performance without sacrificing mathematical simplicity, the power spectral density or Wiener spectrum, of the background scene can be used to establish the magnitude of  $\sigma_n$ . That is,

$$\sigma_n^2 = \delta^2 \int_{K_1}^{K_2} P(K) dk \quad (3)$$

where

$\delta^2$  = IFOV of the detector (sr)

$K$  = spatial frequency

$P(K)$  = 1-D Wiener Spectrum

=  $aK^b$

$a, b$  = constants

Using such a formulation over the white noise approach does more realistically weight the average power in a typical background scene to the lower spatial frequencies but it inadequately models the high frequency spikes



which tend to dominate the false alarm problems. Hence, the Wiener spectrum approach tends to underestimate the false alarm rate.

In addition to the basic accuracy problems, the statistical approach to IRST analyses also suffer from the problem of inflexibility. The formulations above are based on simple threshold crossing logic. And since the time-dependent signal response from each pixel is lost in the statistics, these formulations do not lend themselves to evaluations of various signal processing logics (e.g. multi-color discrimination, spatial discrimination, etc.). Therefore, it appeared reasonable to embark on a new methodology which is embodied in IRSTEM.

IRSTEM is structured such that the user can specify each background element or pixel (typically 4096 elements), each of which can differ from its neighboring elements. The target signature and potential false targets which can vary with time are added and computation of the signals arising from the detectors/preamplifiers is made based on the spectrally varying scene. These signals are modified to incorporate the spatially or temporarily varying effects (e.g. the optical transfer function and the electronic response function). These degradations are modelled by transforming the signal arrays into frequency space and then modifying the signals with the appropriate transfer functions before transforming the entire array back to the time/space domain. At this point, the signal is further degraded by random system noise which then results in a time-dependent signal from each detector/preamplifier which is used by the signal processing routine. The code discussed in this report does not include the signal processing options (e.g. spectral and spatial discrimination, signature growth and adaptive threshold), because the discrimination techniques and the order in which they are applied depend on the specific system design. To determine the range at which the sensor can discriminate the target from the background, the user simply manipulates the preamp signals in exactly the same manner in which the signals are processed by the hardware in the field.

This report summarizes the development of the initial IRSTEM code and includes information contained in the three quarterly reports submitted under this contract (refs. 1, 2 and 3). It should be noted, however, that

some of the information included in those reports has not been duplicated here in the interest of brevity. The structure of the report includes a theoretical section immediately following this introduction. In that section two items not covered in previous reports (i.e., the background model and the sky/haze model) are discussed in addition to the logic flow and basic methodology for each of the major code elements. Whenever the terms are not defined for the equations within the theory section, the reader should refer to the List of Symbols at the front of this report. Section 3 is a concise summary of the codes and major subroutines. It is followed by a user's manual including input and output instructions and a list of major variables used in the code to facilitate code operation and troubleshooting. A sample program is provided to give the user a checkpoint to ensure the proper operation of the code, and a full code listing is included in Appendix A.

It should be noted that some of the features included in IRSTEM as documented here are the result of work done under other contracts. These items include the target signature and the target signature model which was done under SAI Contract N00039-77-C-0409 from the Naval Electronics Command. Three other features (the variable background array specification, input/output representation in wavelength instead of wave numbers, and modification of the integration routine) were funded under AF Contract No. F33615-78-C-1511. The code documented in this report is only the basic program which is expected to undergo extensive modification and expansion as analyses are conducted with it. A discussion of the basic features and limitations of the code as well as a list of recommendations for potential expansions are included in the final section of this report.

## Section 2

### IRSTEM LOGIC AND THEORETICAL BASIS

#### 2.1 Logic Flow

The basic elements of IRSTEM are listed in Table 1 and graphically depicted in Figure 2. The engagement simulator consists of the user specified target dynamics and the specified location and time of day and year for the sensor. The latter specifications are used to determine the sun location for use in the glint and solar scattering computations. At present the target dynamics model is an extremely simple one which assumes that the target is always radially in-bound with no aspect or signature change during the engagement. The only trajectory inputs required are the starting position of the target ( $R_s$ ), its velocity ( $V_T$ ) and the maximum time at which the engagement is to cease ( $T_{max}$ ). However, the engagement simulator is structured such that other modes of operation (e.g. crossing targets, targets with varying flight paths and targets with changing signatures) can be incorporated at a later time. The geometries associated with the engagement space are discussed in subsection 2.2 and followed by discussions of the background models and target signature models in the following subsections.

At present the false target information is assumed to be caused by sun glints, although the user could incorporate flares and other decoys, if desired. Sun glints are modelled in IRSTEM as randomly occurring events in specific cells whose location is specified by the user. The glint irradiance (or voltage response) is added to the aperture irradiance due to the diffuse solar scatter and thermal emission of the background. Even though the glint areas are small compared to an individual background pixel, the glint irradiance dominates the signal response because the energy propagates as a near-collimated beam, whereas the diffuse solar component spreads over a hemispherical solid angle.



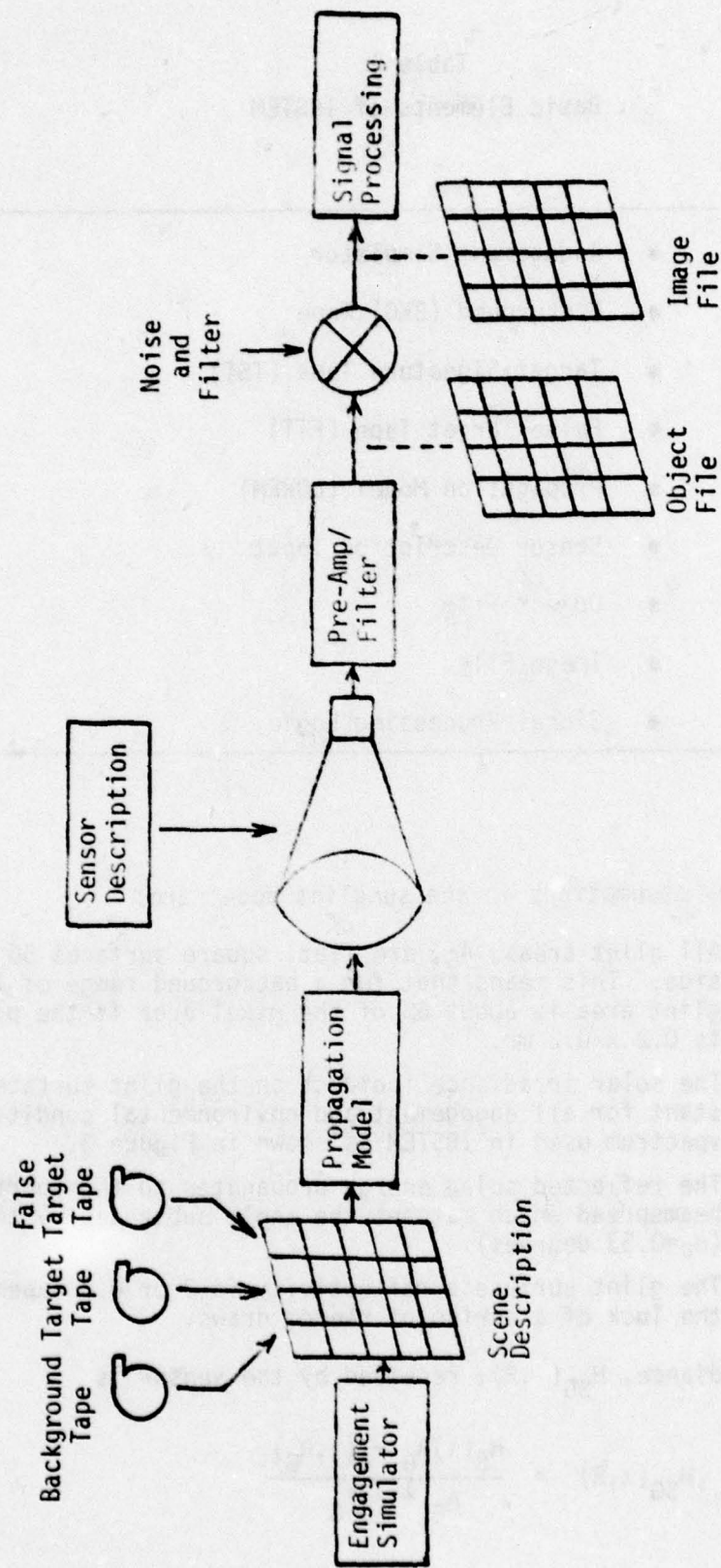


Figure 2. Functional Relationships of Primary Code Elements

Table 1  
Basic Elements of IRSTEM

- Engagement Simulator
- Background (BKG) Tape
- Target Signature Tape (TST)
- False Target Tape (FTT)
- Propagation Model (LOWEM)
- Sensor Description Input
- Object File
- Image File
- Signal Processing Logic

The key assumptions in the sunglint model are:

- (1) All glint areas,  $A_G$ , are flat, square surfaces 50 cm on a side. This means that for a background range of 10 km the glint area is about 6% of the pixel area if the pixel IFOV is  $0.2 \times 0.2$  mr.
- (2) The solar irradiance incident on the glint surface is constant for all engagement and environmental conditions. The spectrum used in IRSTEM is shown in Figure 3.
- (3) The reflected solar energy propagates to the aperture with a beamspread which matches the angle subtended by the sun ( $\theta_0 = 0.53$  degrees)
- (4) The glint surface's reflectivity is 0 or 0.8 depending on the luck of a series of random draws.

The flint irradiance,  $H_{SG}(\lambda, R)$ , received by the sensor is

$$H_{SG}(\lambda, R) = \frac{H_S(\lambda) A_G \tau_A(\lambda, R_G)}{A_G + \theta_0^2 R_G^2} \quad (4)$$

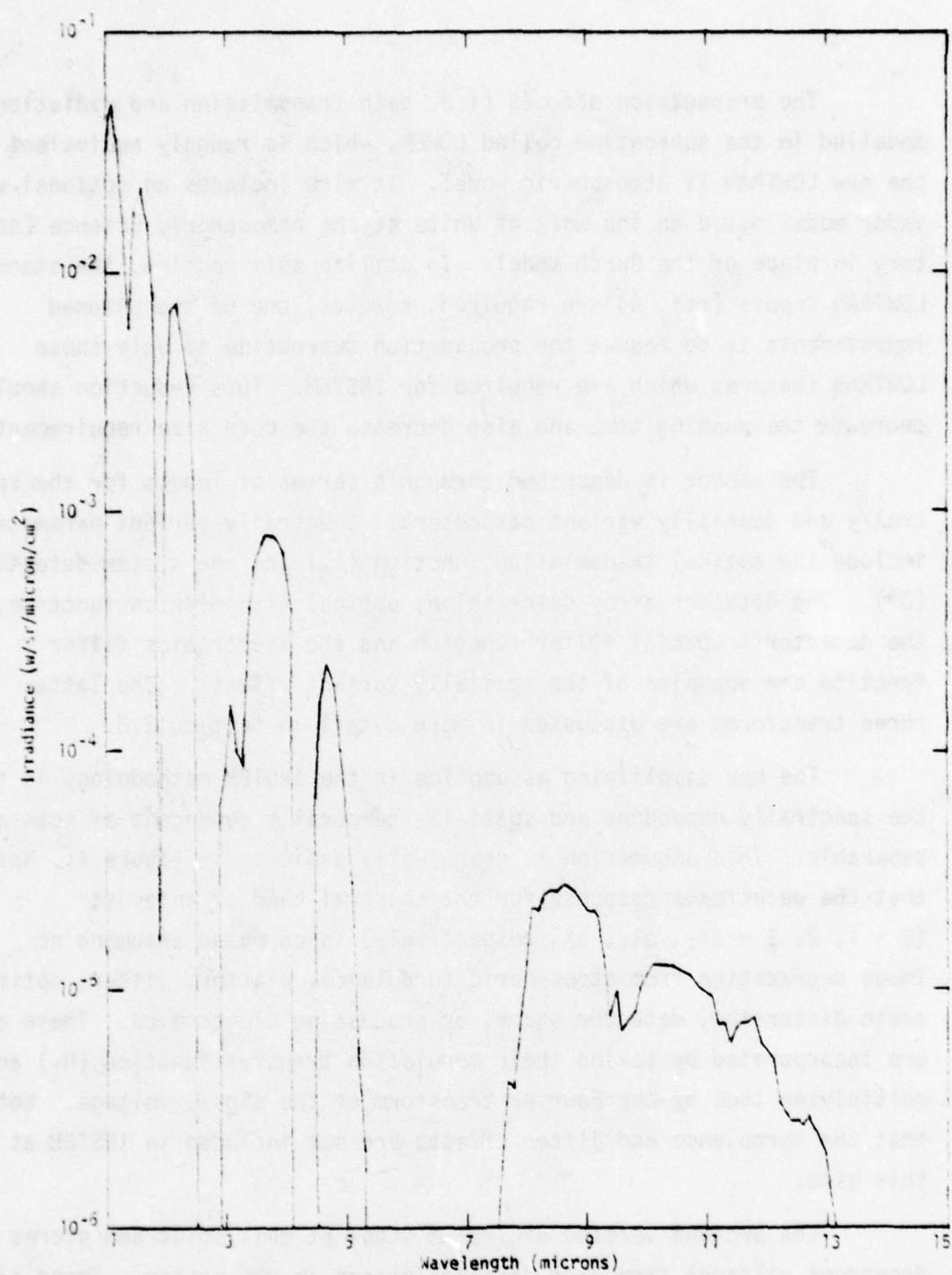


Figure 3. Solar Spectral Irradiance at the Earth's Surface



The propagation effects (i.e. path transmission and radiation) are modelled in the subroutine called LOWEM, which is roughly equivalent to the new LOWTRAN IV atmospheric model. It also includes an optional water vapor model based on the work of White at the Atmospheric Science Laboratory in place of the Burch model. To utilize this routine, the standard LOWTRAN inputs (ref. 4) are required, however, one of the planned improvements is to reduce the propagation subroutine to only those LOWTRAN features which are required for IRSTEM. This reduction should decrease the running time and also decrease the core size requirements.

The sensor is described through a series of inputs for the spectrally and spatially variant parameters. Spectrally variant parameters include the optical transmission function ( $\tau_0$ ) and the system detectivity ( $D^*$ ). The detector array description, optical transmission function, the detector's spatial filter function and the electronics filter function are examples of the spatially variant effects. The latter three transforms are discussed in more detail in Section 2.6.

The key simplifying assumption in the IRSTEM methodology is that the spectrally dependent and spatially/temporally dependent effects are separable. This assumption is graphically depicted in Figure 4. Note that the detector's response for the spectral band of interest ( $\xi = 1, 2, 3 + \Delta\lambda_1, \Delta\lambda_2, \Delta\lambda_3$  respectively) is computed assuming no image degradation from atmospheric turbulence, platform jitter, optical train distortion, detector shape, or processing electronics. These effects are incorporated by taking their modulation transfer function ( $H_i$ ) and multiplying them by the Fourier transform of the signal voltage. Note that the turbulence and jitter effects are not included in IRSTEM at this time.

The present version of IRSTEM stops at this point and stores the time-dependent voltages from each detector/preamp in the system. These signals are generated for each passband of interest as the detector array sweeps across the background scene in the neighborhood of the potential target. Each of these sweeps are updated at the frame time of the detector, which is typically of the order of 1 to 2 seconds. If (a) the proper background scene has been inputted, (b) the target signature is realistic, and (c) the atmospheric inputs and sensor inputs included in the transforms are

Object  
File

$$i_{ij}^{\xi} = \int_{\lambda_{\ell\xi}}^{\lambda_{u\xi}} J(\lambda) \tau_A(\lambda) \tau_0(\lambda) R_d(\lambda) d\lambda$$

Image  
File

$$v_{ij}^{\xi} = F^{-1} \left\{ v_{ij}^{\xi} \right\}$$

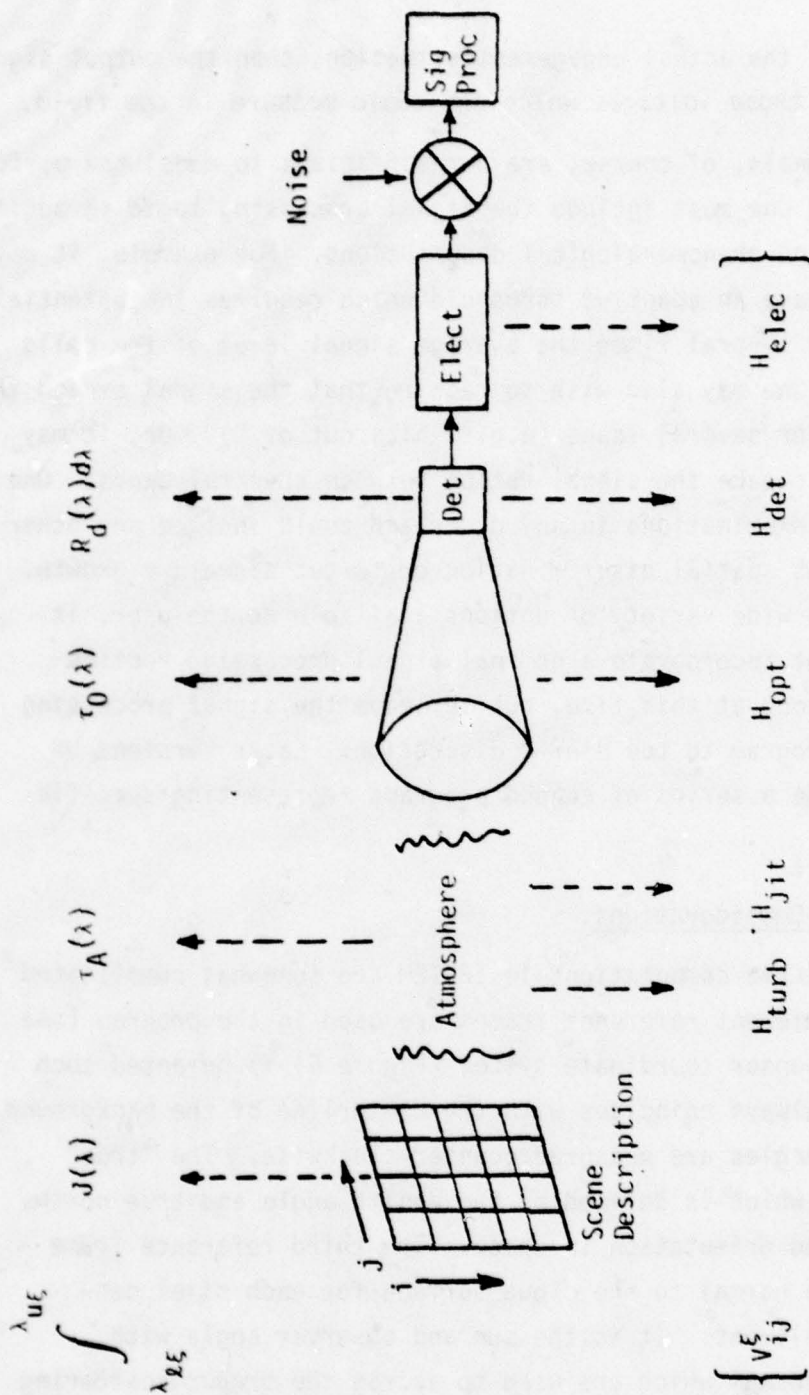


Figure 4. Separation of Spatial and Spectral Computations



characteristic of the actual engagement situation, then the output signals should duplicate those voltages which one could measure in the field.

These signals, of course, are not sufficient to model the performance of the sensor and one must include the signal processing logic in addition to the hardware and phenomenological descriptions. For example, it may be desirable to have an adaptive threshold which requires the potential target cell to be several times the average signal level of the cells surrounding it. One may also wish to require that the signal exceed the threshold level for several scans (e.g. 3 hits out of 5). Or, it may be desirable to compare the signal ratios between spectral bands. One could make these examinations in any order and could include any other techniques such as spatial discrimination or target signature growth. Since there are a wide variety of options available to the user, it was decided to not incorporate a nominal signal processing routine into the IRSTEM code at this time, but to leave the signal processing portion of the program to the user's discretion. Later versions of IRSTEM may include a series of canned programs representing specific hardware.

## 2.2 Geometry Considerations

The geometric computations in IRSTEM are somewhat complicated because three different reference frames are used in the program (see Figure 5). The sensor coordinate system (Figure 6) is oriented such that the y-axis always coincides with the centerline of the background and its azimuth angles are measured counter-clockwise. The "true" reference system which is defined by the zenith angle and true north, always has a fixed orientation in space. The third reference frame is defined by the normal to the cloud surface for each pixel containing a cloud element. It is the sun and observer angle with respect to this normal which are used to access the proper scattering data. The orientation of these reference frames and the pertinent angles used in the background calculations are shown in Figure 7. Note that in this figure RSP refers to the reciprocal sun position, N is the cloud normal, TN is true north, and E is East. The other angles are defined in the list of symbols.

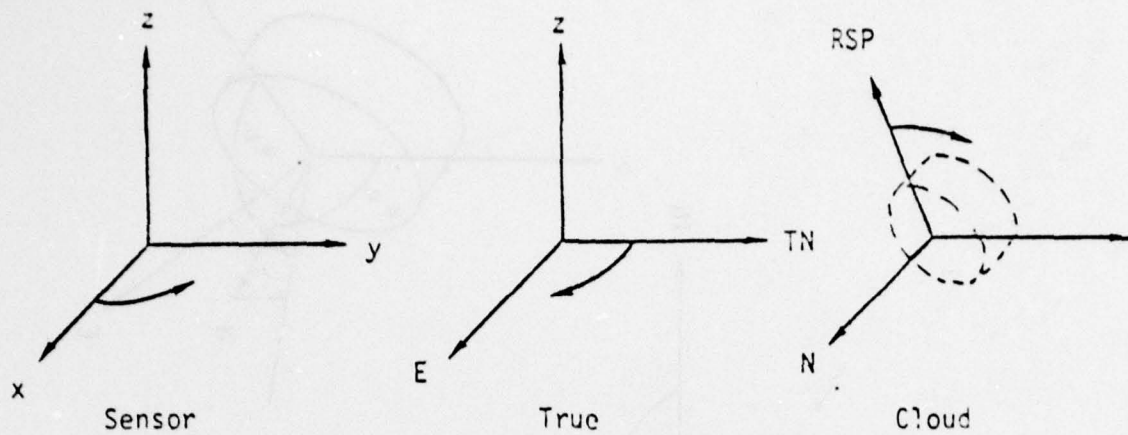


Figure 5. Coordinate Systems.

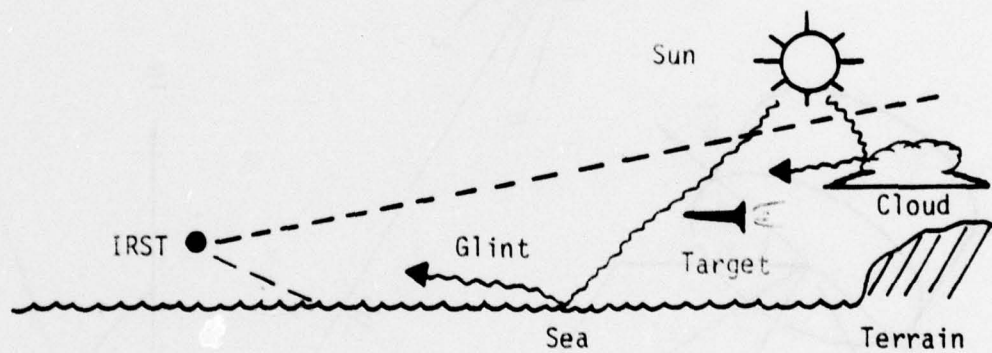


Figure 6a. Pictorial.

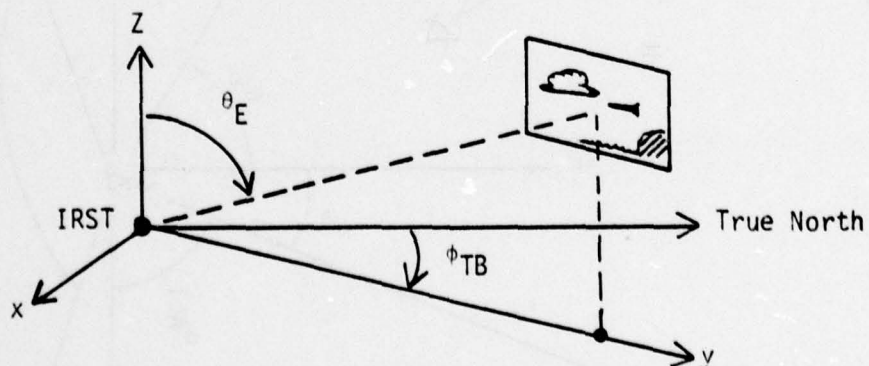


Figure 6b. Schematic

Figure 6. Geometry Sensor Coordinate System.

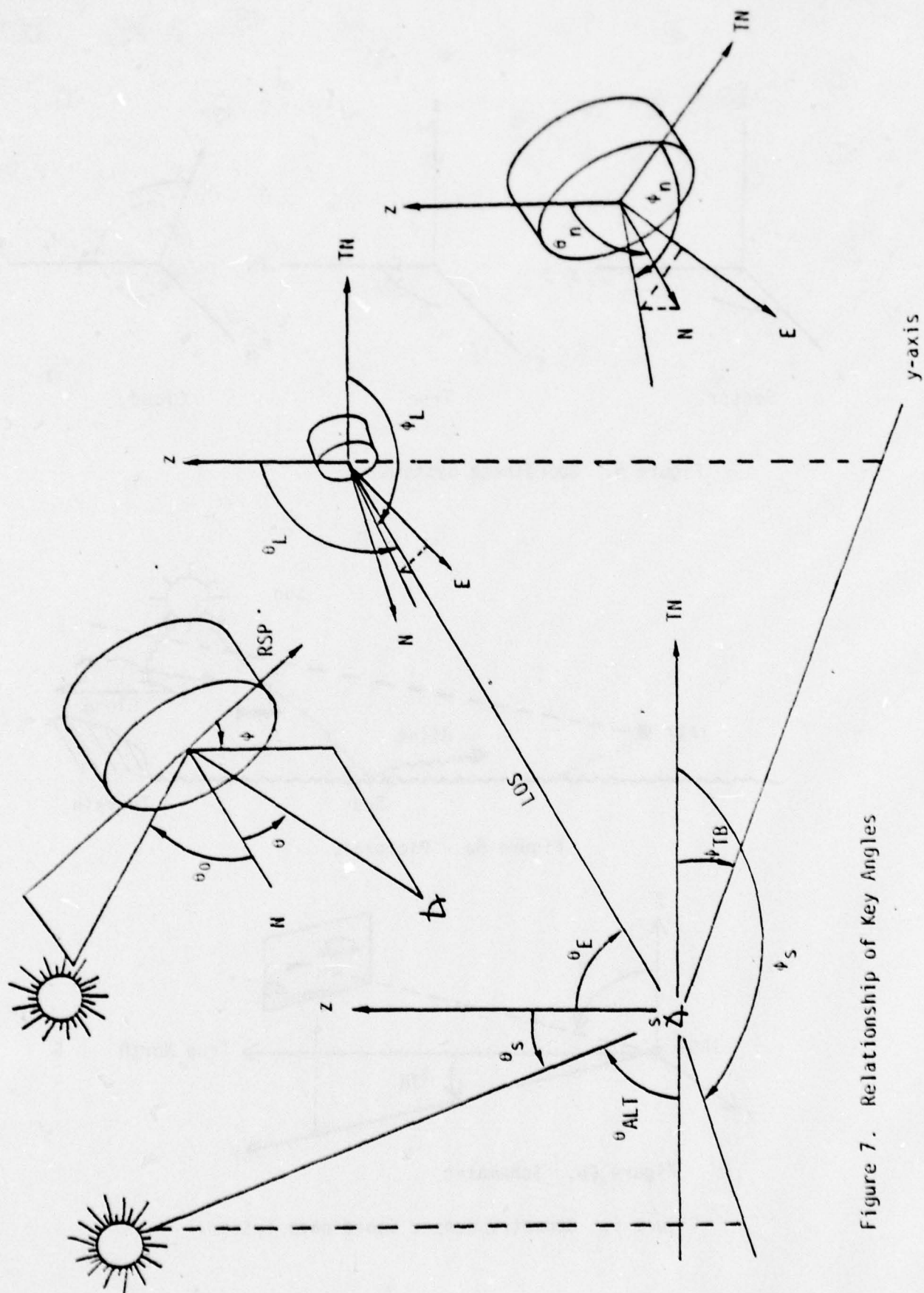


Figure 7. Relationship of Key Angles



Since the background scene is modelled as an array of discrete pixels  $I_{MAX}$  high by  $J_{MAX}$  across, the target's angular position  $(\theta_T, \phi_T)$  must be converted to scene coordinates  $(II, JJ)$  as follows. The target position is compared to the first pixel in the upper left-hand corner  $(\theta_1, \phi_1)$  which can be computed knowing the centroid of the scene  $(\theta_E, \phi = 1.5707 \text{ rad})$  and the pixel size (always assumed to be 0.2 by 0.2 mr). That is,

$$\begin{aligned} II &= \frac{\theta_T - \theta_1}{2 \times 10^{-4}} + 1 \\ &= 5000(\theta_T - \theta_E + I_{MAX} * 10^{-4}) + 1 \end{aligned}$$

and

$$\begin{aligned} JJ &= \frac{\phi_T - \phi_1}{2 \times 10^{-4}} + 1 \\ &= 5000(\phi_T - 1.5707 + J_{MAX} * 10^{-4}) + 1 \end{aligned}$$

Note that the angular coordinates correspond to the lower right-hand corner of the pixel (see Figure 8). Also note that the detector array is assumed to scan the scene from left to right with velocity,  $v_s$ .

### 2.3 Backgrounds Model

Five thermal backgrounds have been generated for IRSTEM. Each background file consists of coded data for a 64 x 64 grid of 0.2 x 0.2 mr pixels. This pixel size was selected to represent the minimum practical detector IFOV.

File 1 on the background tape consists of data for a partly cloudy sky with a 23 km haze. The field-of-view consists of 50% sky, and 50% cloud at a 10 km range (see Figure 9). The cloud is made up of a core with

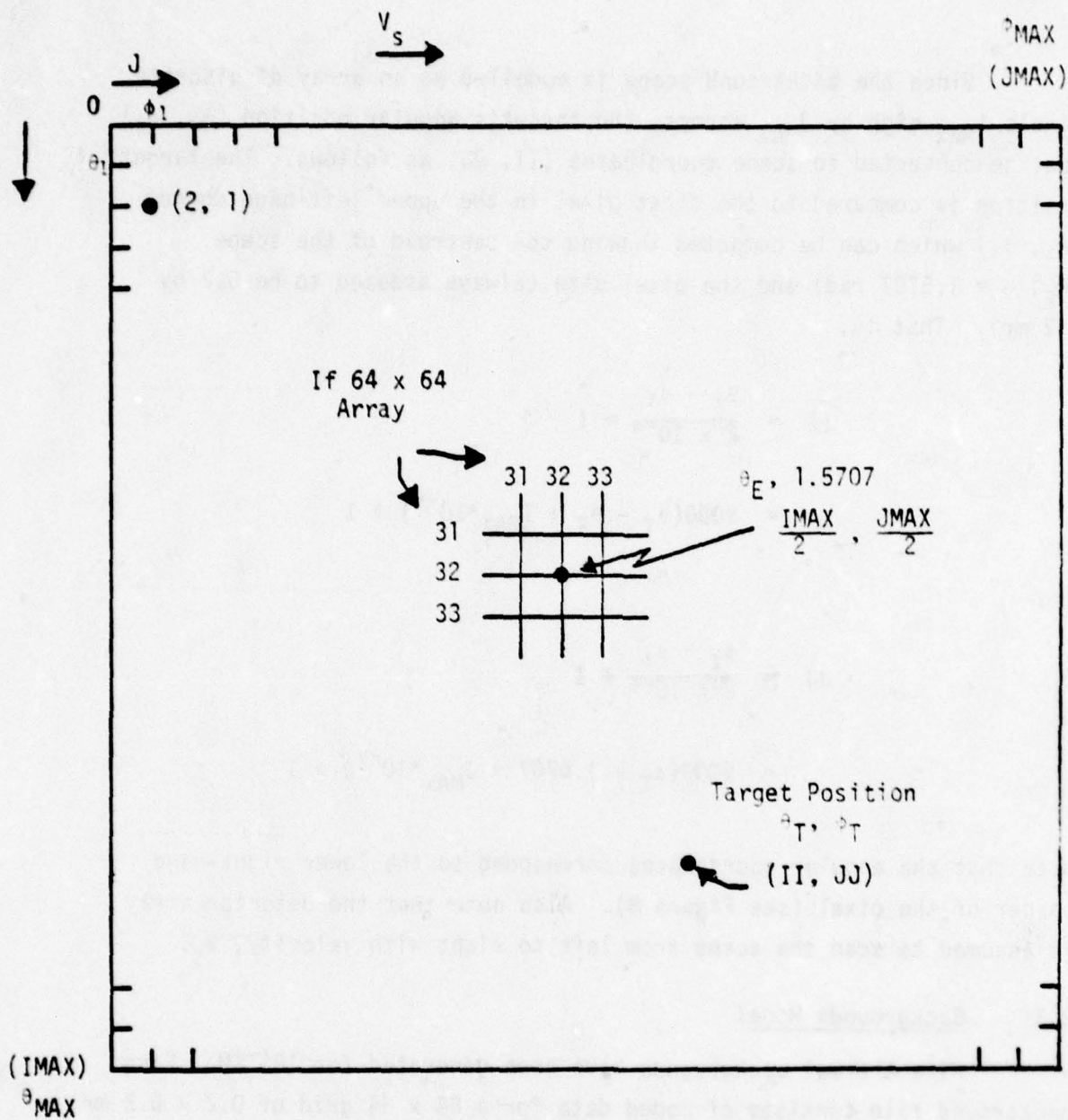
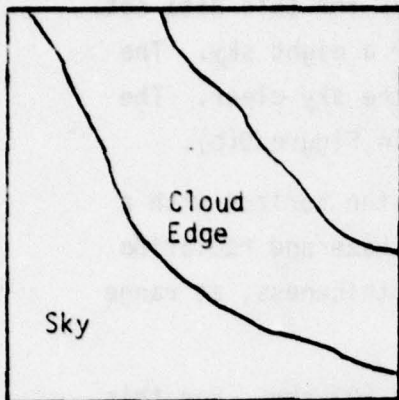
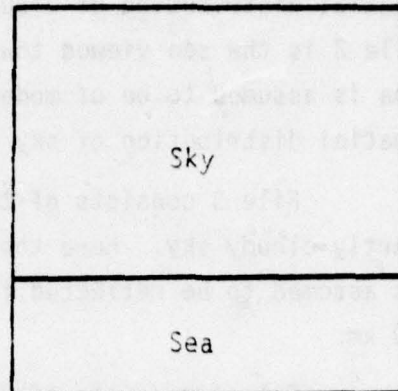


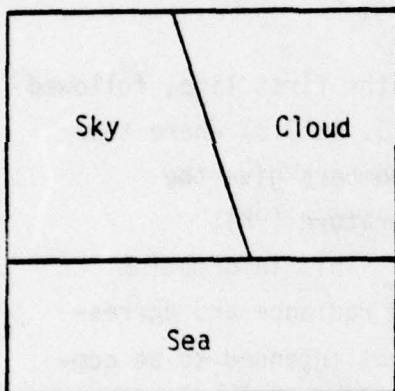
Figure 8. Computing Target Coordinates.



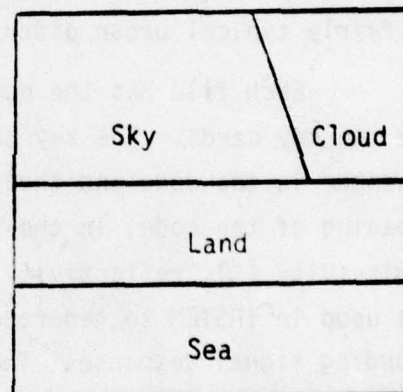
(a) Partly cloudy sky  
23 km haze.



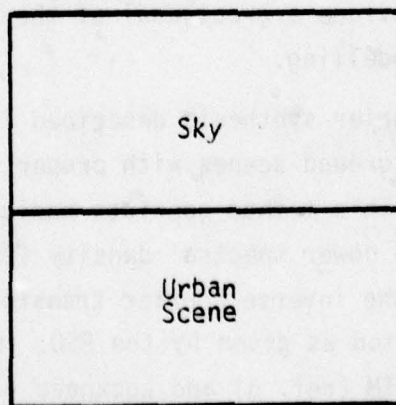
(b) Sea under night sky-  
clear sky, moderate sea



(c) Sea with partly cloudy  
sky-5 km haze, radiation re-  
flected from cloud.



(d) Calm sea, terrain, and sky  
with 23 km haze and radiation  
reflected from cloud.



(e) Urban scene under sky  
with 23 km haze.

Figure 9. Five Nominal Backgrounds.



.5 km thickness and an edge with .1 km thickness; Figure 9(a) shows the spatial distribution of cloud, cloud edge, and sky for this data set. File 2 is the sea viewed toward the horizon under a night sky. The sea is assumed to be of moderate roughness, and the sky clear. The spatial distribution of sky and sea is as shown in Figure 9(b).

File 3 consists of the sea viewed toward the horizon with a partly cloudy sky. Here the sky is given a 5 km haze and radiation is assumed to be reflected from a cloud of 10 km thickness, at range 10 km.

File 4 consists of 25% land, 25% sea, and 50% sky. For this background a 23 km haze was assumed, with radiation reflected from a cloud of 10 km thickness at a range of 10 km.

File 5 is data for an urban scene viewed towards the horizon, with sky under a 23 km haze. Data used was for Flint, Michigan and represents a fairly typical urban distribution.

Each file has the number of key cards in the first line, followed by the key cards. The key cards are formatted (I5, 4E10.3) where the integer is the code and the four floating point numbers give the meaning of the code, in the following order temperature ( $^{\circ}$ K), emissivity (%), reflectivity (%), range (meters). This information is used in IRSTEM to generate the resulting scene radiance and corresponding signal response. These backgrounds are not intended to be completely representative of all possible spatial variations of terrain or sea background. However, the contrast provided by mixing scene types in a given background provides a great deal of the variability required for sensor performance modelling.

The method of Fourier synthesis described in Rusbridge (ref. 5) was used to generate background scenes with proper spatial correlation between scene elements. This method consists basically of multiplying a two-dimensional spatial power spectral density (PSD) by an uncorrelated random array and taking the inverse Fourier transform. The resulting array then has spatial correlation as given by the PSD. One-dimensional PSDs were obtained from the ERIM (ref. 6) and Lockheed (ref. 7) field measurements. An example temperature contour map is shown in Figure 10. In general, there are assumed to be 5 possible temperatures, 2 possible ranges, and 4 possible emissivities for a total of 40 different codes.

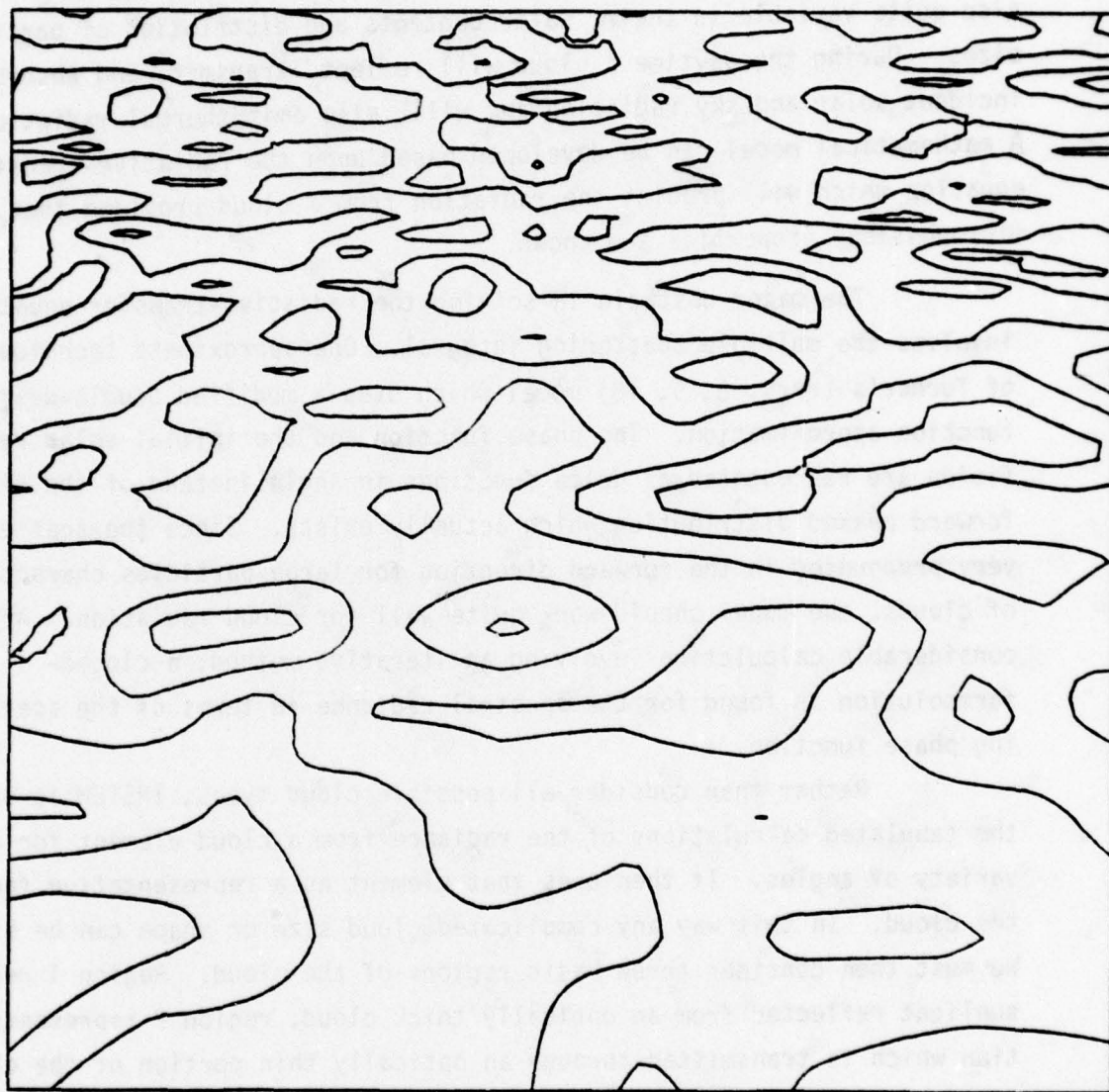


Figure 10 Moderate Sea Used for File 3 Ground Temperature  
Mean 288.95°K Std. Dev. .73°K

Reflectivity is always assumed to be given by Kirchoff's law

$$\rho_{\lambda} = 1 - \epsilon_{\lambda}$$

#### 2.4 Cloud/Haze Model

Clouds appear in an infinite variety of sizes and shapes and are also quite variable in their water contents and distribution of particle sizes. During the daytime a cloud will reflect, transmit, and absorb incident solar and sky radiation and will also emit thermal radiation. A mathematical model can be developed based upon the radiative-transfer equation which will predict the radiation from a cloud provided that the microphysical properties are known.

The major obstacle in solving the radiative-transfer equation involves the multiple scattering integral. One approximate technique is that of Turner's (refs. 8, 9, 10) model which uses a modified double-delta function approximation. The phase function and the initial solar radiation fields are represented as delta functions in angle instead of the highly forward peaked distribution which actually exists. Since the scattering is very pronounced in the forward direction for large particles characteristic of clouds, the model should work quite well for cloud radiation. After considerable calculation involving an iterative method, a closed-form solution is found for the spectral radiance in terms of the scattering phase function.

Rather than consider all possible cloud types, IRSTEM is based on the tabulated calculations of the radiance from a cloud element for a large variety of angles. It then uses that element as a representative facet of the cloud. In this way any complicated cloud size or shape can be simulated. We must then consider three basic regions of the cloud. Region 1 represents sunlight reflected from an optically thick cloud; region 2 represents radiation which is transmitted through an optically thin portion of the cloud edge; and region 3 represents radiation which is emitted from the optically thick cloud. In addition, the radiance for a 5 Km. and a 23 Km. visual range hazes has been calculated and tabulated for IRSTEM by Turner. It was a maritime haze with a real particulate refractive index of 1.5.

To incorporate the cloud/haze radiance data, the user first identifies the background cells in which the cloud is located and specifies the direction of the normal to the cloud surface for that cell. The code then takes the appropriate radiance data from the cloud/haze data files,



interpolating points if required, based on the relationship between the solar angles, viewing angle, and direction of the surface normal. Graphical representations of portions of the data base incorporated in IRSTEM are shown in Figures 11 and 12 for  $\lambda=2 \mu\text{m}$ . All units are given in  $\text{mw/sr/cm}^2/\mu\text{m}$ .

## 2.5 Target Signature Model

A detailed target signature model has been incorporated into the program based on recent SAI work under NAVEXLEX Contract No. N00039-77-C-0409. The various signature components are treated separately to give a physically more realistic model. The radiant intensity from the rocket's plume, tail-pipe, and aerodynamically heated skin are combined to give the overall spectral radiant intensity as a function of aspect angle  $\theta$ , as shown in equation 5.

$$\begin{aligned} J_T(\lambda, \xi) = & J_p(\lambda, 20^\circ) f_p(\xi) \\ & + N^*(T_E, \lambda) \tau_p(\lambda, 160^\circ) A_E(\xi) \\ & + \epsilon_N A_N(\xi) N^*(T_N, \lambda) + \epsilon_S A_S(\xi) N^*(T_S, \lambda) \end{aligned} \quad (5)$$

where

- $J(\lambda, \xi)$  - Spectral radiant intensity ( $\text{w/sr-}\mu\text{m}$ )
- $\tau_p(\lambda, \xi)$  - Plume transmission
- $N^*(\lambda)$  - Blackbody spectral radiance ( $\text{w/cm}^2\text{-sr-}\mu\text{m}$ )
- $A(\xi)$  - Projected area viewed from aspect angle  $\xi$  ( $\text{cm}^2$ )
- $f_p(\xi)$  - Aspect dependence of the plume emission
- $T$  - Temperature ( $^\circ\text{K}$ )
- $\epsilon$  - Emissivity

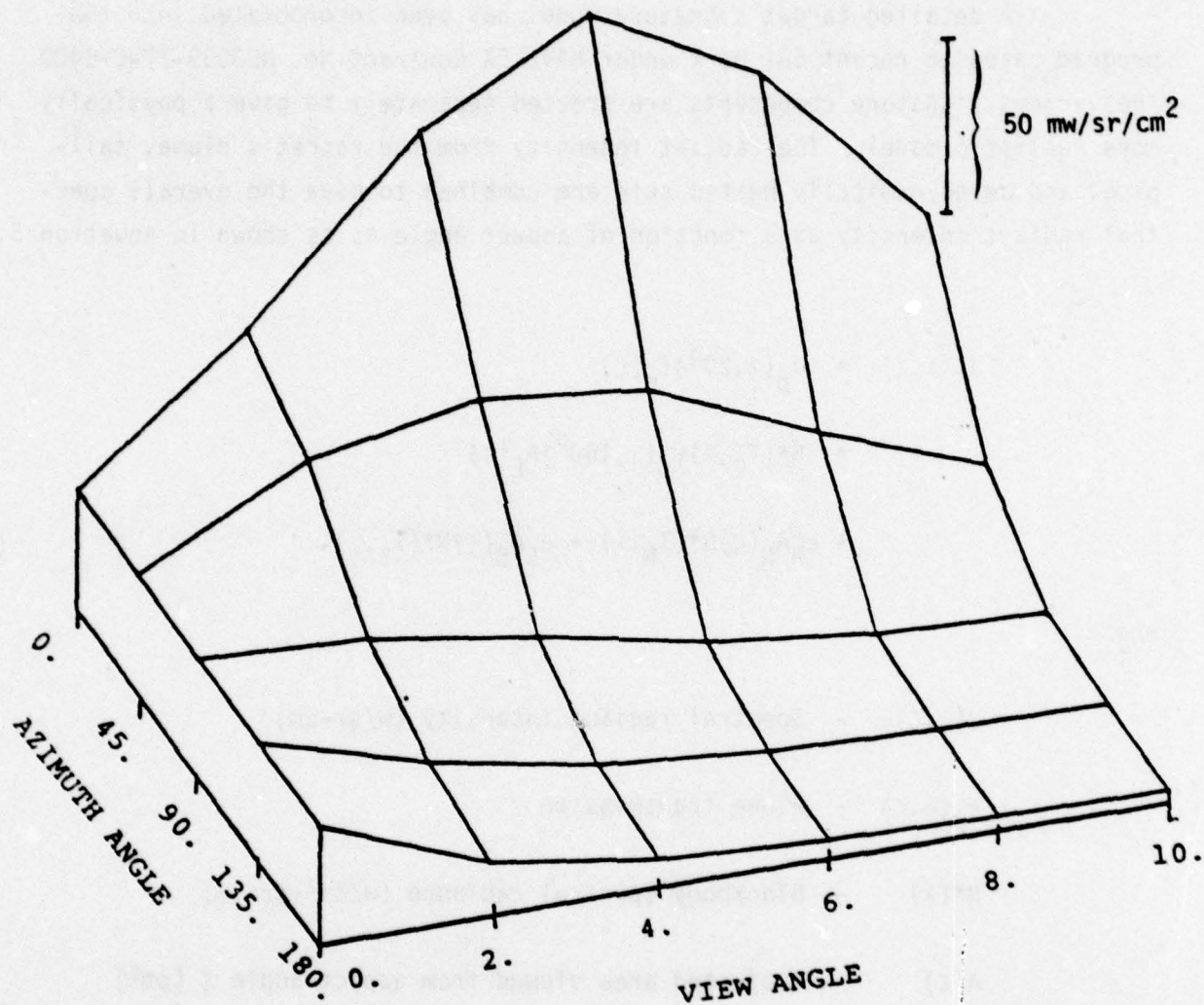


Figure 11. Downward Directed Radiance, 0.1 KM Cloud Thickness  
Solar Zenith Angle is  $60^\circ$ .

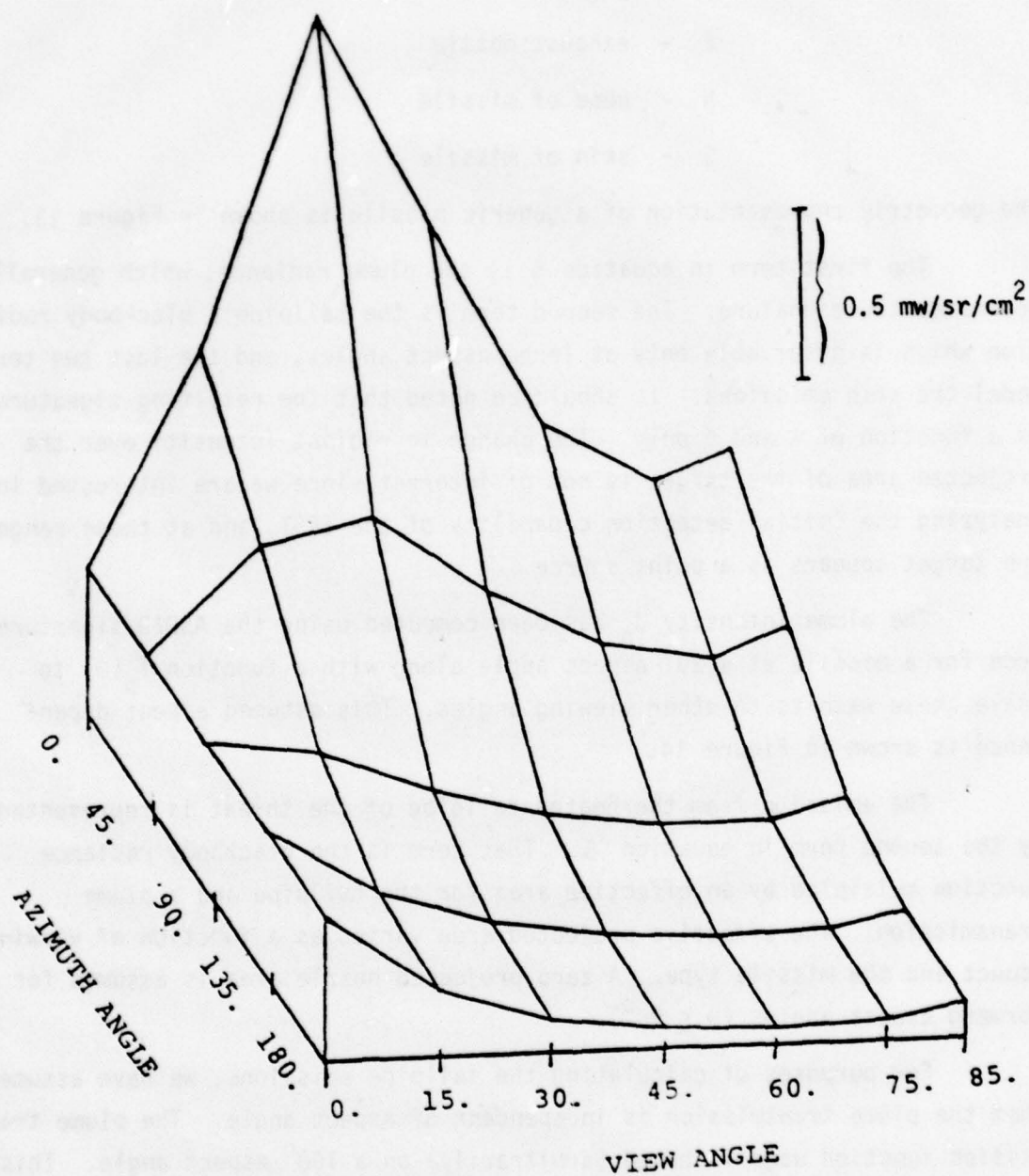


Figure 12. Downward Directed Radiance through Haze 23 KM Visual Range  
Solar Zenith Angle is 30°.



T - total  
 p - plume  
 E - exhaust nozzle  
 N - nose of missile  
 S - skin of missile

The geometric representation of a generic missile is shown in Figure 13.

The first term in equation 5 is the plume radiance, which generally dominates the signature. The second term is the tailpipe's blackbody radiation which is observable only at large aspect angles, and the last two terms model the skin emissions. It should be noted that the resulting signature is a function of  $\lambda$  and  $\theta$  only. The change in radiant intensity over the projected area of the target is not of interest since we are interested in analyzing the initial detection capability of the IRST, and at these ranges the target appears as a point source.

The plume intensity  $J_p$  has been computed using the ASDIR signature code for a missile at a  $20^\circ$  aspect angle along with a function  $f_p(\theta)$  to scale these results to other viewing angles. This assumed aspect dependence is shown in Figure 14.

The emission from the heated tailpipe of the threat is represented by the second term in equation 5. That term is the blackbody radiance function multiplied by an effective area for the tailpipe and a plume transmission. The effective projected area varies as a function of viewing aspect and the missile type. A zero projected nozzle area is assumed for forward aspect angles ( $\theta \leq 90^\circ$ ).

For purposes of calculating the tailpipe emissions, we have assumed that the plume transmission is independent of aspect angle. The plume transmission function used is based (arbitrarily) on a  $160^\circ$  aspect angle. This function is shown in Figure 15 along with a  $110^\circ$  curve for comparison which shows that the assumption to not vary the plume transmission as a function of aspect angle is a reasonable one.

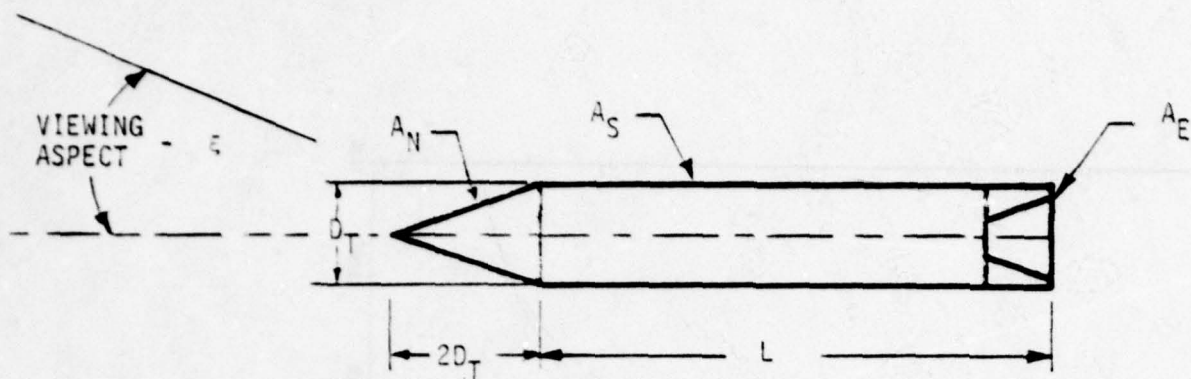


Figure 13. Assumed Missile Geometry.

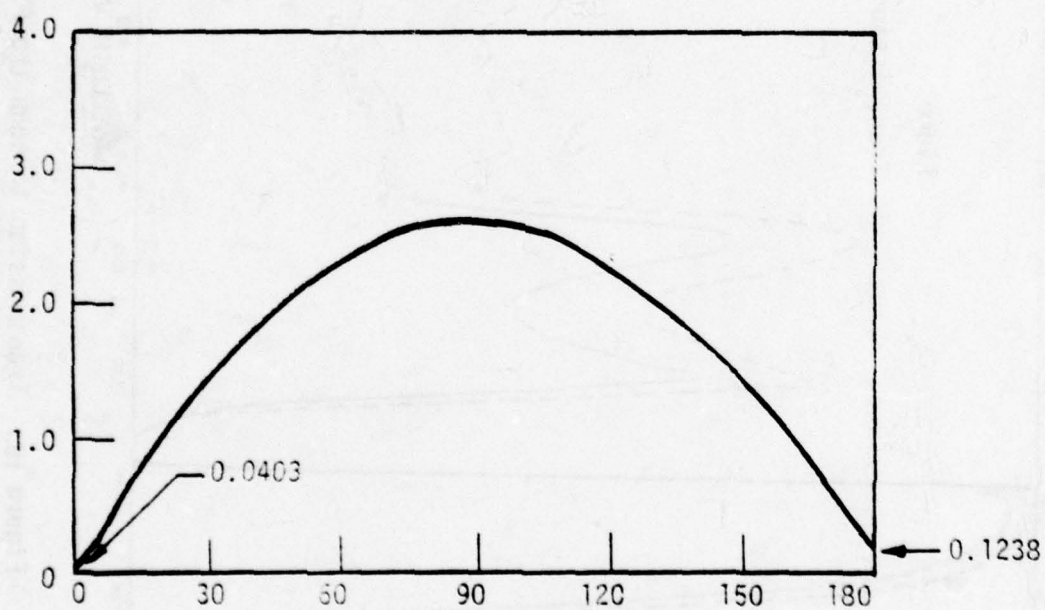


Figure 14. Aspect Angle Dependence of Plume Emission.

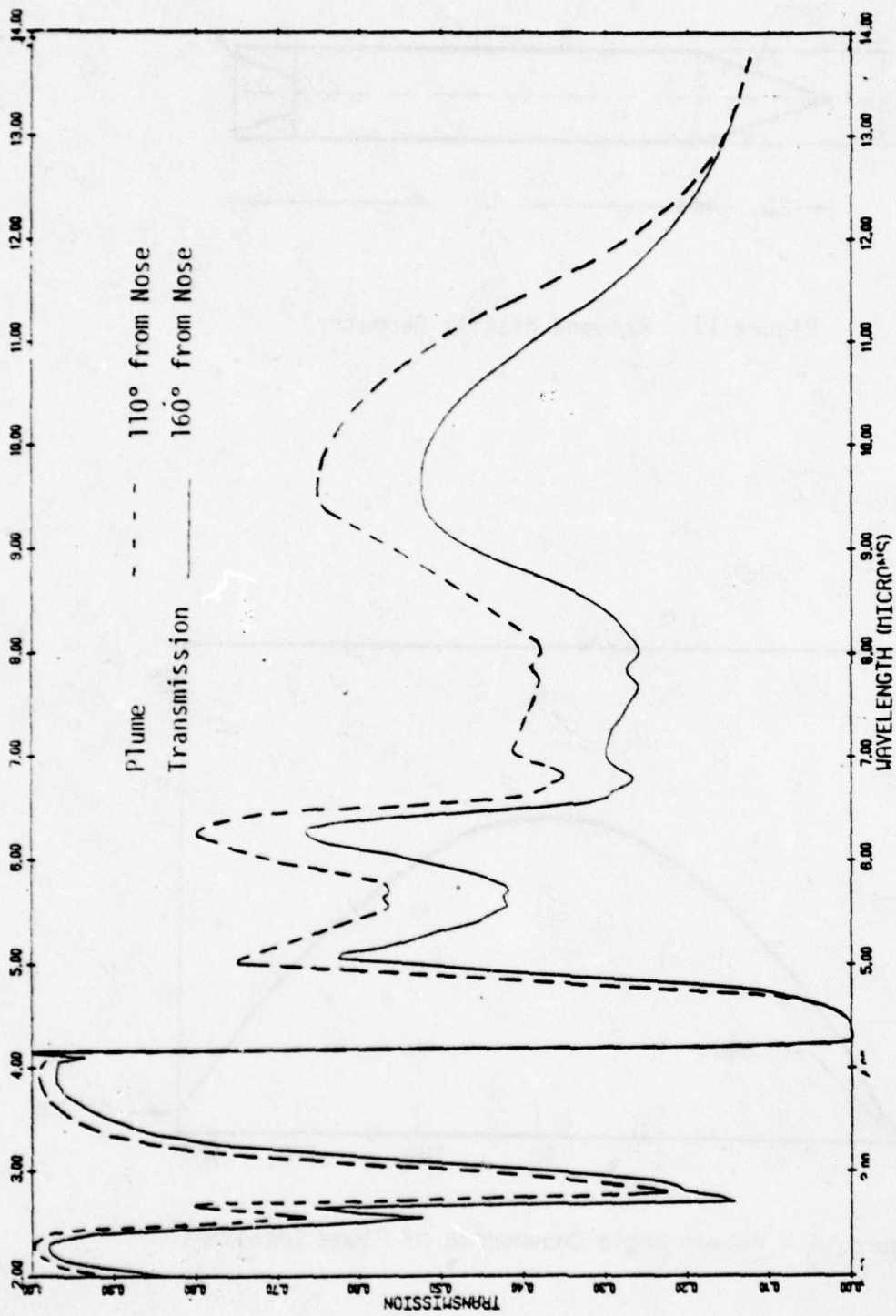


Figure 15. Transmission through the Plume for a 110° and 160° Viewing Geometry to the Exhaust Nozzle.



The missile nose and skin emissions are computed based simply on the product of the blackbody function and a projected area. The radiance from aerodynamic heating is divided into two terms so that higher temperature (at or near the stagnation temperature) can be assumed for the nose of the missile and more moderate temperature assumed for the rest of the skin.

The various portions of a typical missile signature and the resultant total signature are shown in Figures 16, 17, 18 and 19. Note that these example plots are based on viewing the missile from the rear, which is not consistent with the present trajectory mode of only radially in-bound targets (ref. Section 2.1). This generalized signature model which includes the tailpipe emissions has been developed in anticipation of a more general trajectory model in later versions of IRSTEM which will model crossing targets.

## 2.6 Sensor Model

### 2.6.1 Methodology.

If we assume the projection of the detector array moves across the background scene as shown in Figure 20, the ideal voltage generated at the output of the detector due to any given pixel is

$$\begin{aligned} v_{\text{ideal}}(\bar{\rho}) &= \int_{\Delta\lambda} N(\lambda, \bar{\rho}) A_{\text{BKG}} \tau_A(\lambda) \tau_O(\lambda) \Omega_c R_d(\lambda) d\lambda \\ &= \pi D^2 10^{-8} \int_{\Delta\lambda} N(\lambda, \bar{\rho}) \tau_A(\lambda) \tau_O(\lambda) R_d(\lambda) \end{aligned} \quad (6)$$

assuming 0.2 x 0.2 mr pixels.

Equation (6) is a manifestation of one of the key simplifying assumptions used in IRSTEM; namely, the separability of the spectrally and spatially dependent effects.

To compute the spatially-dependent effects (or temporally dependent effects since  $x = v_s t$ ), we consider 3 distortions: the sensor optics, the finite detector size, and the electronics response. The optical distortions are incorporated by convolving the ideal voltage with the optical point spread function (PSF) to produce an effective signal response,  $V_{\text{eff}}$ .

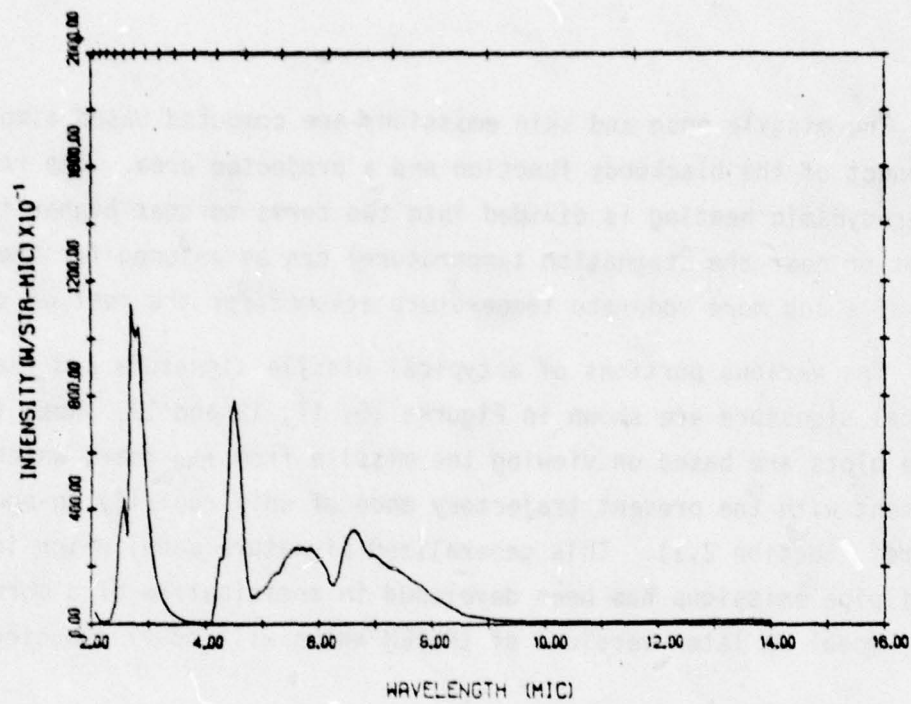


Figure 16. Typical Plume Signature.

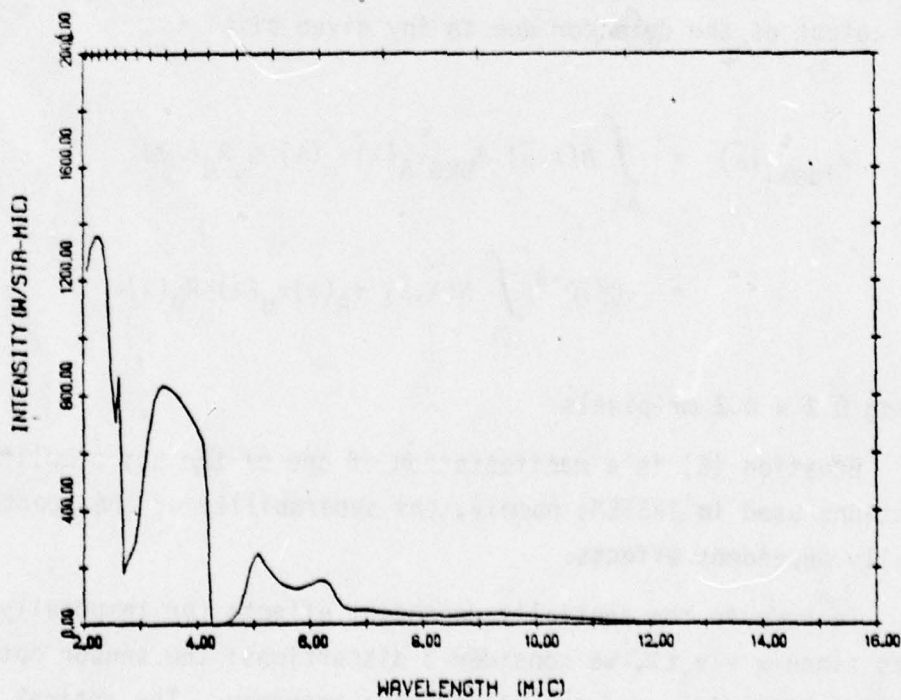


Figure 17. Typical Exhaust Nozzle Signature.

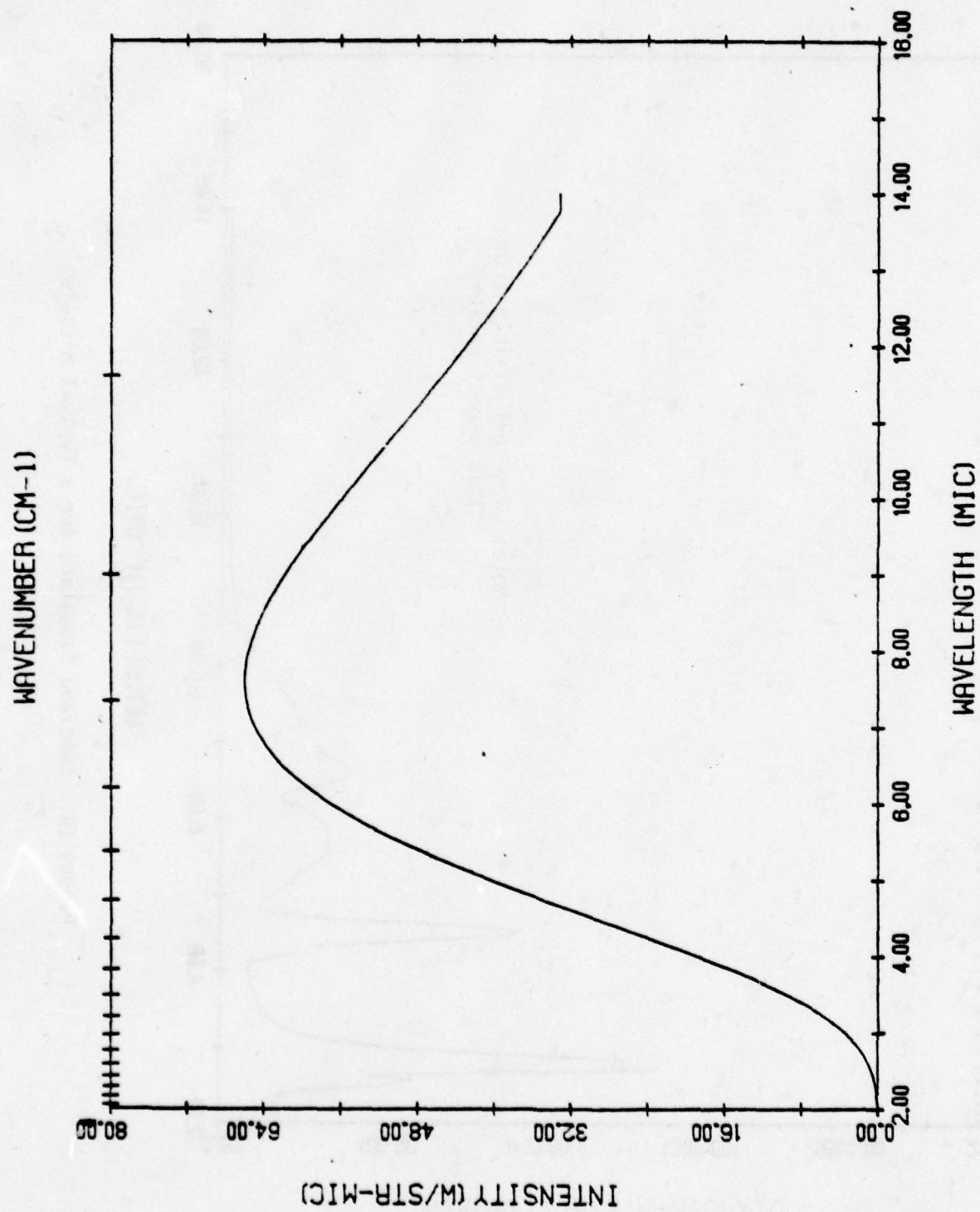


Figure 18. Typical Skin Signature.



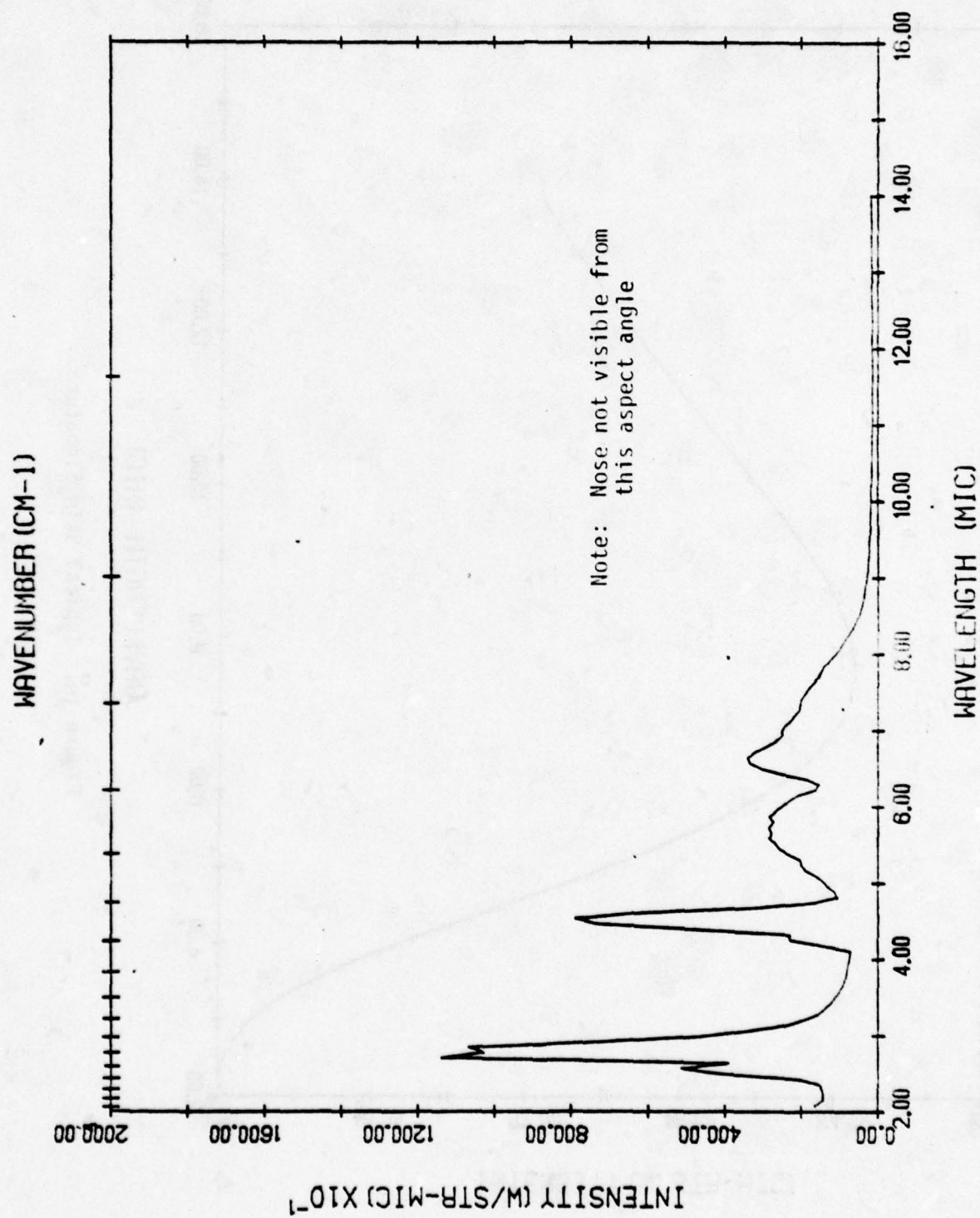


Figure 19. Combined Signature for a Typical Missile.

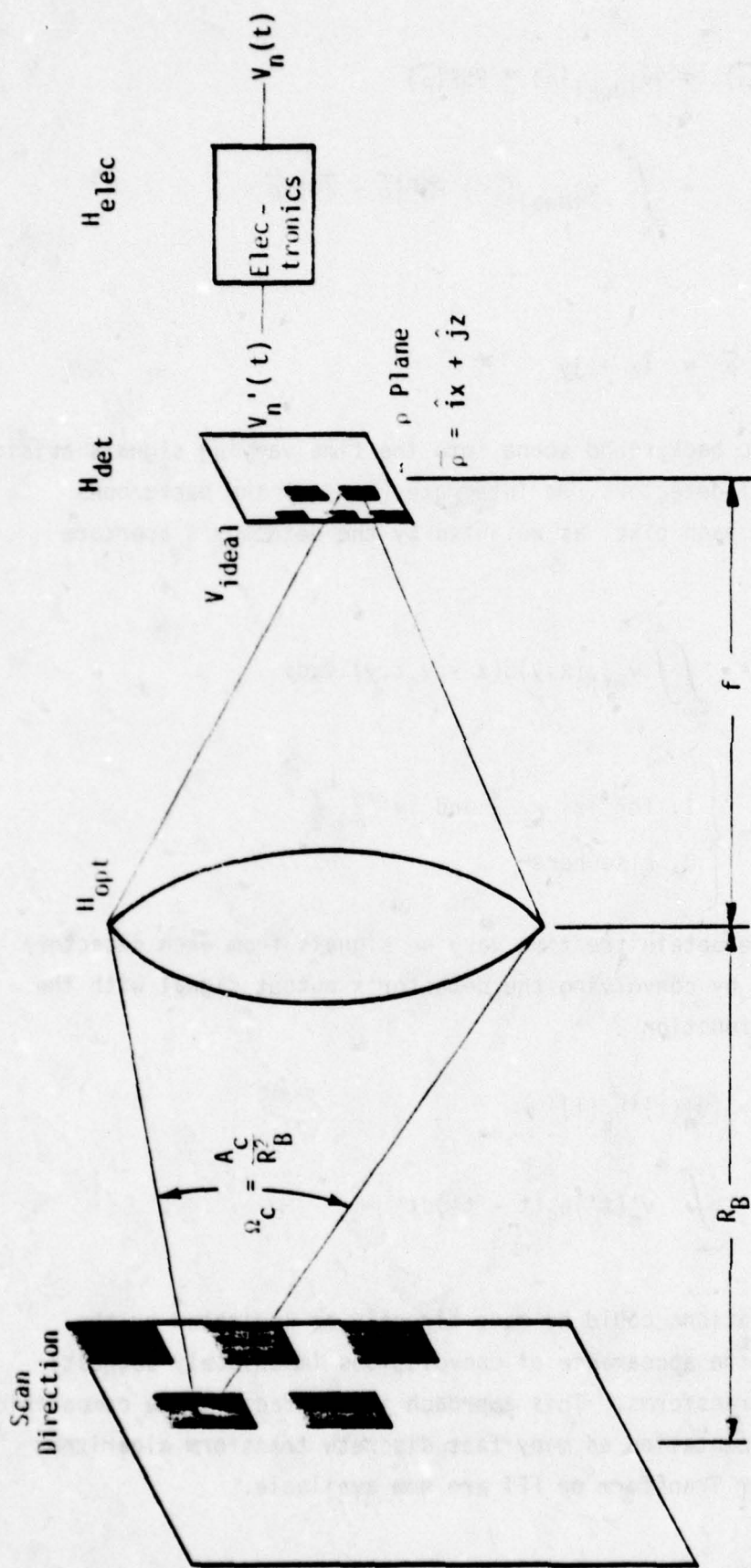


Figure 20. Projection of Array on Background.

$$\begin{aligned}
v_{\text{eff}}(\bar{\rho}) &= v_{\text{ideal}}(\bar{\rho}) * \text{PSF}(\bar{\rho}) \\
&= \int_{-\infty}^{\infty} v_{\text{ideal}}(\bar{\rho}') \text{PSF}(\bar{\rho} - \bar{\rho}') d\bar{\rho}'
\end{aligned} \tag{7}$$

where

$$\bar{\rho} = \hat{i}x + \hat{j}y$$

To convert the static background scene into the time varying signals arising from the  $n$  individual detectors, we integrate (or sum) the background signals arising from each pixel as weighted by the detector's aperture function.

$$v_n'(t) = \iint_{-\infty}^{\infty} v_{\text{eff}}(x,y) d(x - v_s t, y) dx dy \tag{8}$$

where

$$d(x,y) = \begin{cases} 1, & \text{for } |x| \leq \frac{L_x}{2} \text{ and } |y| \leq \frac{L_y}{2} \\ 0, & \text{elsewhere} \end{cases}$$

Finally, we obtain the time varying signals from each detector/preamplifier circuit by convolving the detector's output signal with the electronic response function

$$\begin{aligned}
v_n(t) &= v_n'(t) * h_E(t) \\
&= \int_{-\infty}^{\infty} v_n'(t') h_E(t - t') dt'
\end{aligned} \tag{9}$$

The computations could be made directly as indicated by the equations; however, the appearance of convolutions immediately suggests the use of Fourier transforms. This approach is, in fact, quite compatible with a digital implementation as many fast discrete transform algorithms like the Fast Fourier Transform or FFT are now available.



Defining the one- and two-dimensional transform pairs as

$$f(t) = \frac{1}{2\pi} \int_{-\infty}^{\infty} F(\omega) e^{i\omega t} d\omega$$

where

$$F(\omega) = \int_{-\infty}^{\infty} f(t) e^{-i\omega t} dt$$

and

$$f(\vec{\rho}) = f(x, y) = \frac{1}{4\pi^2} \iint_{-\infty}^{\infty} F(k_x, k_y) e^{i(k_x x + k_y y)} dk_x dk_y$$

where

$$F(k_x, k_y) = \iint_{-\infty}^{\infty} f(x, y) e^{-i(k_x x + k_y y)} dx dy,$$

we can rewrite equations 7, 8 and 9.

$$v_{\text{eff}}(\vec{k}) = v_{\text{ideal}}(\vec{k}) H_{\text{opt}}(\vec{k}) \quad (10)$$

$$\text{Since, } v'_n(t) = \iint_{-\infty}^{\infty} v_{\text{eff}}(k_x, k_y) H_{\text{det}}(k_x, k_y) e^{ik_x v_s t} dk_x dk_y,$$

$$\begin{aligned} v'_n(\omega) &= \iint_{-\infty}^{\infty} v_{\text{eff}}(\vec{k}) H_{\text{det}}(\vec{k}) \left[ \int_{-\infty}^{\infty} e^{i(k_x v_s t - \omega t)} dt \right] dk_x dk_y \\ &= \iint_{-\infty}^{\infty} v_{\text{eff}}(\vec{k}) H_{\text{det}}(\vec{k}) \delta(v_s k_x - \omega) dk_x dk_y \end{aligned}$$

$$= \frac{1}{v_s} \int_{-\infty}^{\infty} v_{\text{eff}}\left(\frac{\omega}{v_s}, k_y\right) H_{\text{det}}\left(\frac{\omega}{v_s}, k_y\right) dk_y \quad (11)$$

and

$$V_n(\omega) = H_E(\omega) V_n'(\omega) \quad (12)$$

Therefore we can combine equations 10, 11, and 12 and compute  $v_n(t)$  as

$$v_n(t) = \frac{1}{2\pi} \iint_{-\infty}^{\infty} v_{\text{ideal}}(k_x, k_y) H_{\text{opt}}(k_x, k_y) H_{\text{det}}(k_x, k_y) H_{\text{elec}}(v_s k_x) \cdot e^{ik_x v_s t} dk_x dk_y$$

In other words, the transformed ideal voltage array is modified by the appropriate transform for the optics, detectors and electronics to create a new array which is inverse transformed to generate the resultant time-dependent signal response from each detector.

#### 2.6.2 Sensor Transforms.

The transfer functions which are currently built into IRSTEM are summarized as follows:

##### Optics - Circular Clear Aperture

$$H_{\text{opt}}(k) = \frac{2}{\pi} [\cos^{-1} A - A\sqrt{1-A^2}]$$

where

$$A = \frac{\lambda F k}{2\pi D}$$

$F$  = Focal length

$D$  = Aperture diameter

Note also that  $k_x = 2\pi/X$ ,  $X = 0$  to  $X_{\text{max}}$  where  $X_{\text{max}}$  is the linear extent of the background image in the focal plane.

### Detectors - Rectangular

$$H_{\text{Det}}(\mathbf{k}) = A_d \left( \text{sinc} \frac{k_x L_x}{2} \right) \left( \text{sinc} \frac{k_y L_y}{2} \right)$$

where

$H_{\text{Det}}$  = Detector response

$A_d$  = Detector area =  $L_x L_y$

$\bar{\mathbf{k}}$  = Spatial frequency vector,  $\hat{i}k_x + \hat{j}k_y$

$\text{sinc}(x) = \sin(x)/x$

### Electronics - Low-Pass Filter

$$H_{\text{Elec}}(k_x v_s) = \frac{1}{\sqrt{1 + \left( \frac{k_x v_s}{2\pi f_0} \right)^2}}$$

where

$v_s$  = Image scan rate across the detectors =  $\frac{2\pi F}{T_s}$

$f_0$  = Filter cutoff frequency

$F$  = Focal length

$T_s$  = Scan time

Even though these transforms are currently hardwired into IRSTEM, the user can replace them with alternative expressions. With some slight code modification, the user can even specify the physical characteristics of the hardware (e.g. aperture shape, obscurations, and distortions) and then use the Fast-Fourier Transform to compute the frequency response function when an analytical expression is not readily available.



### 2.6.3 Other Sensor Considerations

#### Selecting Appropriate Detector Response

The image array which results from the inverse transform operation discussed above is based on the full number of pixels in the background scene. Since the instantaneous field-of-view (IFOV) of the detectors are generally larger than  $0.2 \times 0.2$  mr pixels, the rows corresponding to the center of the detector are selected to represent the output signals and the rest of the array is discarded. The determination of which rows correspond to detector centers proceed as shown in Figure 21. The number of detectors falling fully within the vertical scene dimension is computed using the detector length and degree of overlap with the next detector.

$$N = \frac{Y - L_y}{L_y - OVL} + 1$$

The detector centers are at

$$y_i = \frac{L_y}{2} + (i-1)(L_y - OVL)$$

or pixel numbers

$$II = y_i / (2 \times 10^{-4} F) + 1$$

since the top edge of the first detector always coincides with the top edge of the scene. In the example shown in Figure 21, all dimensions are normalized to the pixel size as follows.

$$Y = 18.5 \quad OVL = 1$$

$$L_y = 5$$

which implies  $N = 4$  with detector centers at 3, 7, 11 and 15.

#### System Noise.

Random system noise (e.g. thermal, shot, or  $1/f$  noise) is modelled in IRSTEM by modifying the image file voltages by a random number,  $\bar{v}_n$ ,

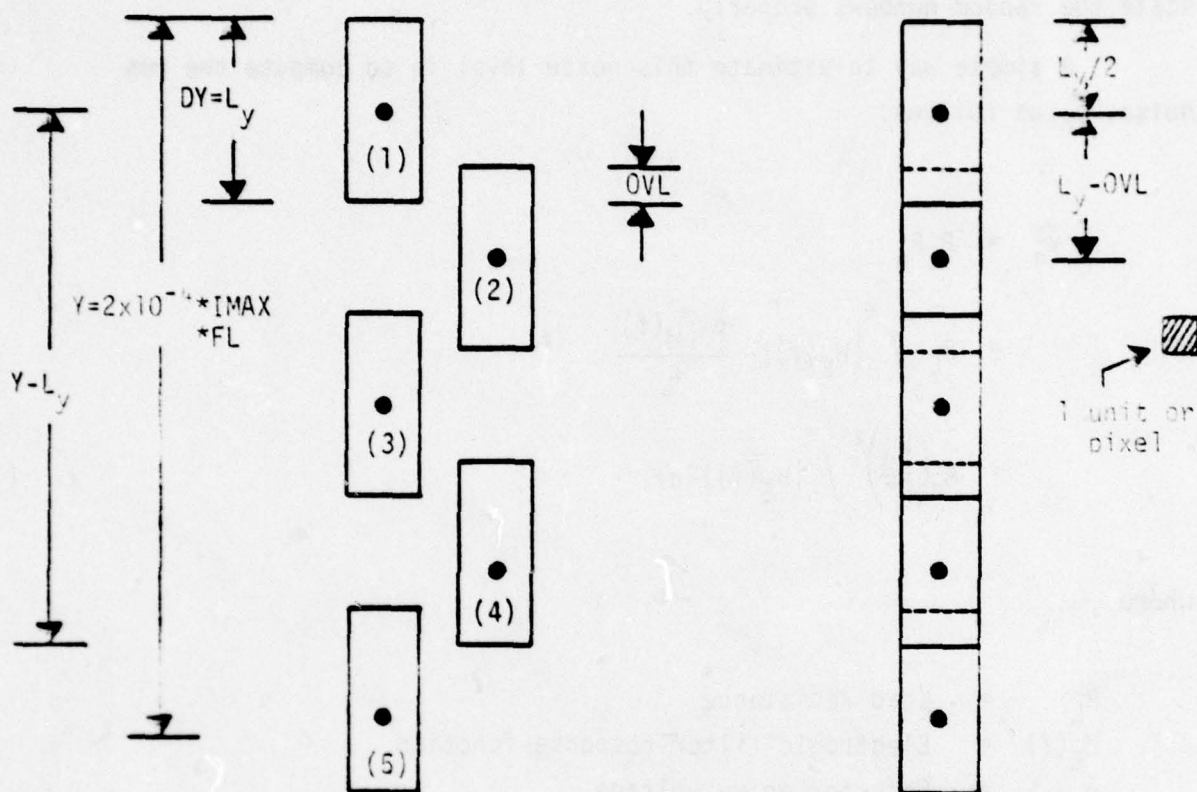


Figure 21. Determination of Detector Centers.

which is uncorrelated from cell to cell (see Figure 22). A random number sequence of 299 numbers with zero mean and unity standard deviation is built into the code. The user must input the rms noise level (or standard deviation since we are assuming Gaussian statistics) to allow the program to scale the random numbers properly.

A simple way to estimate this noise level is to compute the rms noise,  $\bar{v}_n$  as follows:

$$\begin{aligned}
 \bar{v}_n^2 &= R_L P_n \\
 &= R_L \int_0^\infty |H_E(f)|^2 \frac{dv_{nd}^2(f)}{R_L} \\
 &= A_d \left( \frac{R_d}{D^*} \right)^2 \int_0^\infty |H_E(f)|^2 df
 \end{aligned} \tag{13}$$

where

$$\begin{aligned}
 R_L &= \text{Load resistance} \\
 H_E(f) &= \text{Electronic filter response function} \\
 v_{nd} &= \text{Detector noise voltage} \\
 &= \frac{R_d}{D^*} \sqrt{A_d \Delta f} \\
 R_d &= \text{Responsivity} \\
 D^* &= \text{Detectivity} \\
 A_d &= \text{Detector area}
 \end{aligned}$$

Note that the system noise is simply the detector noise modified by the filter response function. This response function must be integrated over the frequency interval of interest to properly account for the additional noise input due to the filter's limited bandpass since the filter response function already has been convolved with the object file, the optical point-spread function, and the detector response. If we have an ideal low-



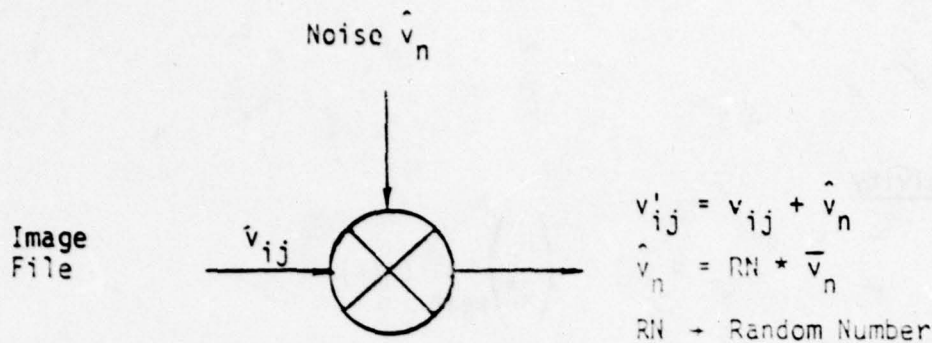


Figure 22. Random Noise Input to IRSTEM

pass filter with cutoff  $f_0$ , the integral in equation (13) is simply  $f_0$ ; if the response function is  $1/(1+f/f_0)$ , the result is  $\pi f_0/2$ . This implies the rms noise input can be given by

$$\bar{v}_n = K \left( \frac{R_d}{D^*} \right)_{\text{peak}} \sqrt{A_d f_0}$$

where  $K = 1$  for an ideal low-pass filter  
 $= \sqrt{\pi/2}$  for a more realistic low-pass filter

The peak values for  $R_d$  and  $D^*$  are shown because they are readily available from the detector manufacturers. These values are also required inputs along with  $D^*(\lambda)$  to compute the spectral responsivity. That is, the code computes

$$R_d(\lambda) = \left( \frac{R_d}{D^*} \right)_{\text{peak}} D^*(\lambda)$$

We do not require  $R_d(\lambda)$  to be user specified since this information is not as readily available as  $R_{d \text{ peak}}$ ,  $D^*_{\text{peak}}$ , and  $D^*(\lambda)$ .

## 2.7 Summary of Equations

The basic equations used in IRSTEM are summarized below in approximate order of appearance. The list of symbols at the front of this report defines each parameter.

### Responsivity

$$R_d(\lambda) = \left( \frac{R_d}{D^*} \right)_{\text{peak}} D^*(\lambda)$$

### Passband in Wavenumbers

$$\nu_L = 5 \left\lfloor \frac{10^4}{5\lambda_u} \right\rfloor, \quad \left\{ \right\} \text{ implies integer value}$$

$$\nu_u = 5 \left\lfloor \frac{10^4}{5\lambda_L} \right\rfloor + 1$$

$$\Delta\nu = 5 \left\lfloor \frac{10^4 \Delta\lambda}{5\lambda_L^2} \right\rfloor$$

### Blackbody Function

$$W(\lambda) = \frac{c_1}{\lambda^5 \left( \exp(c_2/\lambda T) - 1 \right)}$$

### Static Background

$$\begin{aligned} V_{\text{ideal}} = & \pi D^2 10^{-8} \left[ 10 \int_{\Delta\lambda} N_A \tau_o R_d d\lambda + \frac{\rho_D 10^4}{\pi} \int_{\Delta\lambda} H_s \tau_A \tau_o R_d d\lambda \right. \\ & \left. + \frac{10^4 \epsilon_B}{\pi} \int_{\Delta\lambda} W \tau_A \tau_o R_d d\lambda \right] \end{aligned}$$

### Cloud/Sky Background

$$V_{\text{ideal}} = \pi D^2 10^{-8} \left[ 10 \int N_A \tau_o R_d d\lambda + 10 \int N_C \tau_o \tau_A R_d d\lambda \right]$$

### Sunglints

$$V_{\text{ideal}} = V_{\text{ideal}} (\text{before glint}) + V_G$$

$$V = \frac{RN\pi D^2 \rho_g K 10^4}{4} \int H_S^T A^T O R_d d\lambda$$

where

$$K = \frac{2500}{0.25 + 8.7 \times 10^{-5} R_G^2}$$

### Target Cell

$$V_{\text{ideal}} = V_{\text{ideal}} (\text{before target}) \left( 1 - \frac{A_T 10^8}{4R^2} \right) + \pi D^2 10^{-8} \left[ 10^4 \int J_T^T A^T O R_d d\lambda + 10 \int N_A^T O R_d d\lambda \right]$$

where

$$J_T = J_T(\lambda, 20^\circ) F_p(\xi) + N^*(T_E, \lambda) \tau_p(\lambda, 160^\circ) A_E(\xi) + \epsilon_N A_N(\xi) N^*(T_N, \lambda) + \epsilon_S A_S(\xi) N^*(T_S, \lambda)$$

### Optical Transfer Function

$$H_{\text{Opt}}(\vec{k}) = \frac{2}{\pi} \left[ \cos^{-1} A - A \sqrt{1 - A^2} \right]$$

where  $A = \frac{\lambda F k}{2\pi D}$

### Detector Transfer Function

$$H_{\text{Det}}(\vec{k}) = A_d \left( \text{sinc} \frac{k_x L_x}{2} \right) \left( \text{sinc} \frac{k_y L_y}{2} \right)$$



### Electronics Transfer Function

$$H_{\text{Elec}}(k_x v_s) = \frac{1}{\sqrt{1 + \left(\frac{k_x v_s}{2\pi f_0}\right)^2}}$$

### Interpolation

$$Y_{\text{new}} = Y_{j-1} + \left(\frac{\lambda_{\text{new}} - \lambda_{j-1}}{\lambda_j - \lambda_{j-1}}\right)(Y_j - Y_{j-1})$$

### Target Cell Location

$$II = 5000(\theta_{\text{TS}} - \theta_E + I_{\text{max}}/10^4) + 1$$

$$JJ = 5000(\phi_{\text{TS}} - 1.5707 + J_{\text{max}}/10^4) + 1$$

### Sun Location

$$\theta_{\text{ALT}} = \sin^{-1}[\sin(\text{Lat})\sin(\text{Dec}) + \cos(\text{Lat})\cos(\text{Dec})\cos(\text{Lha})]$$

$$\phi_S = \cos^{-1}\left\{\frac{[\sin(\text{Dec}) - \sin\theta_{\text{ALT}}\sin(\text{Lat})]}{[\cos\theta_{\text{ALT}}\cos(\text{Lat})]}\right\}$$

### Cloud Coordinate Transformation

$$\theta_0 = \cos^{-1}[\sin\theta_n \sin\theta_s \cos(\phi_n - \phi_s) + \cos\theta_n \cos\theta_s]$$

$$\theta = \cos^{-1}[\sin\theta_n \sin\theta_L \cos(\phi_n - \phi_L) + \cos\theta_n \cos\theta_L]$$

$$\phi = 180^\circ - \cos^{-1} \left[ \frac{\cos \theta_d - \cos \theta \cos \theta_0}{\sin \theta \sin \theta_0} \right]$$

where

$$\theta_d = \cos^{-1} [\sin \theta_L \sin \theta_S \cos(\phi_L - \phi_S) + \cos \theta_L \cos \theta_S]$$

### Section 3 PROGRAM SUMMARY

In this section the IRSTEM code is reviewed to identify its major elements and the methodology for combining these elements. The sub-routines are listed along with a functional description and the inputs and the outputs associated with each subroutine. Specific instructions for operating the code are discussed in Section 4.

#### 3.1 Overall Program Flow.

The top level flow diagram for IRSTEM is shown in Figure 23. The program begins by reading the background codes associated with each pixel. Then the code keys are read to specify the temperature emissivity, reflectivity and range associated with each unique background code. Since these codes may not be numbered consecutively, the codes are reordered to make them sequential reserving codes 1 through 6 for sky and cloud data.

After the background information has been fixed, the scene is scanned to identify duplicate ranges to minimize calls to LOWEM later in the program. Also at this time, the minimum and the maximum ranges for the entire background scene are identified although they are not used in this version of IRSTEM. Anticipated modifications to minimize the computational time probably will use this minimum/maximum range.

Since LOWTRAN (i.e. Subroutine LOWEM) requires regular wavenumber spacings ( $\Delta v$  or CV) that are multiples of  $5 \text{ cm}^{-1}$ , the integrations to form the  $V_{\text{ideal}}$  arrays must be done in terms of  $\lambda$  spacings which correspond to equal  $v$  intervals. These spacings are fixed in the early part of the program as follows:

$$(1) \quad \Delta v = \left\{ \frac{10^4}{5\lambda_L^2} \Delta \lambda \right\} 5$$

$$(2) \quad v_L = \left\{ \frac{10^4}{5\lambda_u} \right\}$$

$$(3) \quad v_u = \left\{ \frac{10^4}{5\lambda_L} + 1 \right\} 5$$



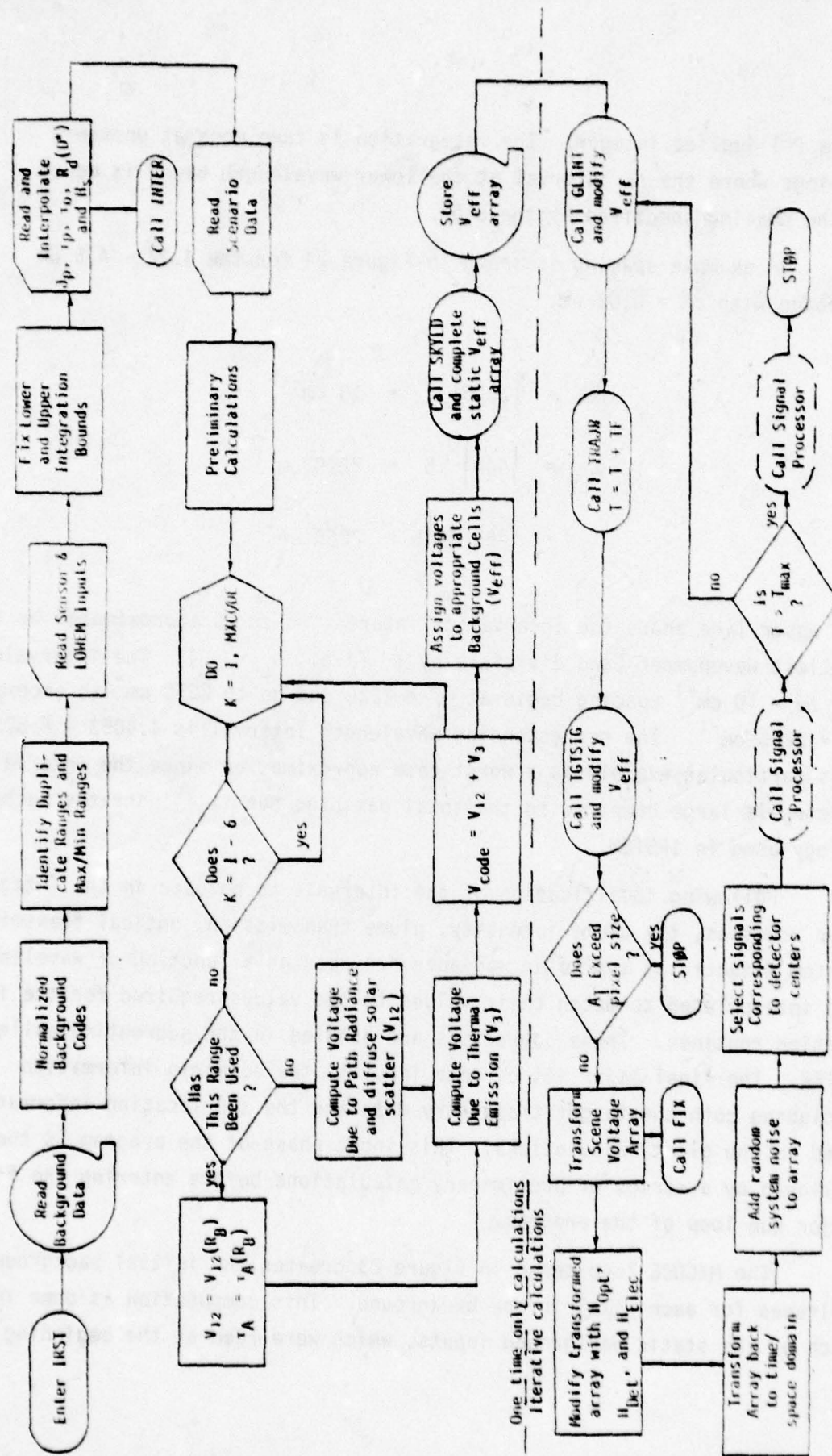


Figure 23. IRSTEM Flow Chart.

where { } implies integer. The integration is then done at uneven  $\lambda$  spacings where the  $\Delta\lambda$  interval at the lower wavelength bound is equal to the spacing specified by the user.

An example spacing is shown in Figure 24 for the 4.42 - 4.5  $\mu\text{m}$  passband with  $\Delta\lambda = 0.02 \mu\text{m}$ .

$$\Delta\nu = \left\{ 2.05 \right\} 5 = 10 \text{ cm}^{-1}$$

$$\nu_L = \left\{ 444 \right\} 5 = 2220 \text{ cm}^{-1}$$

$$\nu_U = \left\{ 453.49 \right\} 5 = 2265 \text{ cm}^{-1}$$

The upper line shows the interval of interest which is approximated by the smallest wavenumber band divisible by  $\Delta\nu$  (i.e.,  $\nu_L - \nu_U$ ). The intervals for  $\Delta\nu = 10 \text{ cm}^{-1}$  spacing begin at  $\nu_L = 2220$  and go to  $2270 \text{ cm}^{-1}$  to encompass  $\nu_U = 2265 \text{ cm}^{-1}$ . The corresponding wavelength interval is 4.4053 - 4.505  $\mu\text{m}$ . This particular example is a worst case approximation since the interval spacing is large compared to the total passband but it illustrates methodology used in IRSTEM.

Following specification of the intervals to be used in the integration routines, the plume intensity, plume transmission, optical transmission system detectivity and solar radiance are read as a function of wavelength and interpolated to match their values to the values required for the integration routines. These operations are handled in the subroutine called INTER. The final major set of data input is the scenario information including both the target trajectory data and the sun location information used in the glint calculations. This input phase of the program is then followed by a series of preliminary calculations before entering the first major due loop of the program.

The MXCODE loop shown in Figure 23 creates the initial background voltages for each pixel in the background. This computation is done for each of the static background inputs, which were read at the beginning

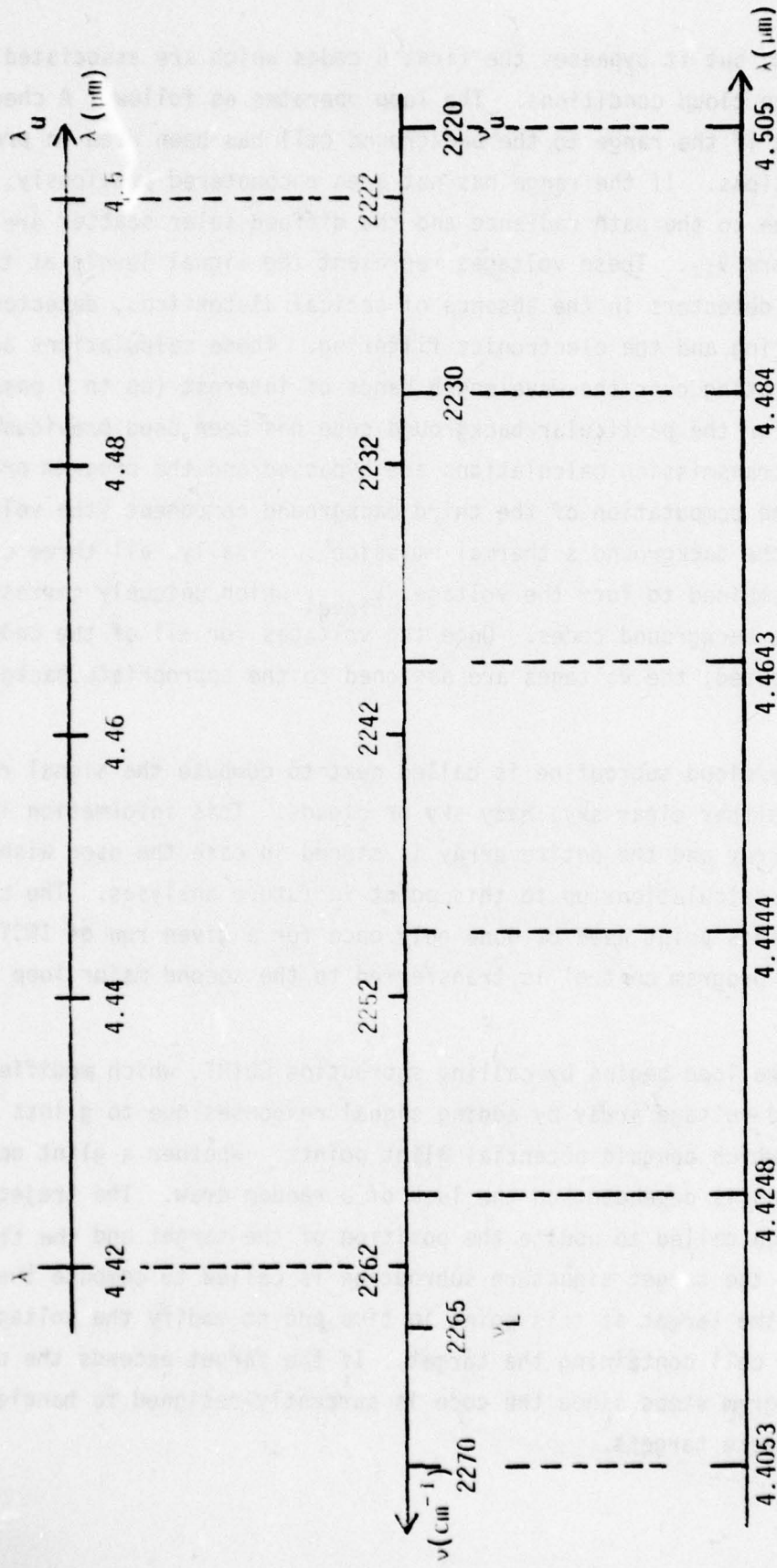


Figure 24. Example. Interval Specification.



of the program, but it bypasses the first 6 codes which are associated with the sky and the cloud conditions. The loop operates as follows: A check is made to see if the range to the background cell has been used in previous calculations. If the range has not been encountered previously, the voltage due to the path radiance and the diffuse solar scatter are combined to form  $V_{12}$ . These voltages represent the signal levels at the output of the detectors in the absence of optical distortions, detector spatial filtering and the electronics filtering. These calculations are made by integrating over the wavelength bands of interest (up to 3 passbands). If the range for the particular background code has been used previously, the  $V_{12}$  and path transmission calculations are bypassed and the program proceeds directly to the computation of the third background component (the voltage array due to the background's thermal emission). Finally, all three components are combined to form the voltage,  $V_{ideal}$  which uniquely corresponds to each of the background codes. Once the voltages for all of the codes have been computed, the voltages are assigned to the appropriate background cells ( $V_{eff}$ ).

The sky/cloud subroutine is called next to compute the signal responses arising from either clear sky, hazy sky or clouds. This information is added to the  $V_{eff}$  array and the entire array is stored in case the user wishes to bypass the calculations up to this point in future analyses. The calculations to this point need be done only once for a given run of IRSTEM. At this point program control is transferred to the second major loop - the time loop.

The time loop begins by calling subroutine GLINT, which modifies the background voltage array by adding signal responses due to glints to the cells which contain potential glint points. Whether a glint occurs on a given scan is dependent on the luck of a random draw. The trajectory routine is then called to update the position of the target and the time clock. Next, the target signature subroutine is called to compute the signature of the target at this point in time and to modify the voltage array for the cell containing the target. If the target exceeds the pixel size, the program stops since the code is currently designed to handle only point-source targets.

Now the scene array is ready for transformation to the frequency domain so that the array can be modified by the sensor induced distortions. This transformation is accomplished by calling subroutine FIX which controls the calls to the fast-Fourier transform subroutine (FOURT). Once the transformation is complete, the transformed array is modified by the optical transmission function, the detector transmission function and the electronics transmission function to create a new array which is transformed back to the time/space domain. Next, random noise is then added to each of the scene cells based on the normalized rms noise input specified by the user and the result of a random number draw. Finally, those rows corresponding to the sensor specified by the detector geometry are selected for manipulation by the signal processing routine. The rest of the information is dropped from the file.

At this point, the signal processing subroutine could be called by the user to analyze the performance of the search set. As noted earlier, this routine is not included at this time because of its unique relationship to each specific hardware design. The data presently is stored on a file in anticipation that a signal processing routine will be called after the time loop is completed; perhaps the signal processor will even be written as a separate program. It is anticipated that the signal processing routine will analyze the raw video signals generated by IRSTEM to determine at what point the target can be detected based on the discrimination techniques employed.

### 3.2 Subroutines and Functions

The subroutines and functions called by the main program are listed alphabetically in Table 2. Most of these routines are discussed further in the paragraphs below. Some of the more simple routines (e.g., DUMR and INTEG) are not reviewed; the LOWEM subroutines (HNO3, POINT and ANGL) are also not reviewed since they are described in reference 4. Summary tables, for each subroutine except those associated with LOWEM, are provided at the end of this subsection to delineate input/output variables.

Table 2.  
IRSTEM Subroutines and Functions

<u>Subroutine</u>	<u>Purpose</u>
ANGL	LOWEM subroutine to compute zenith angle.
DUMR	Dummy read routine.
FIND	Selects data sets for sky/cloud radiance interpolations.
FIX	Calls Fast Fourier Transform and reorders the result of the transformation.
FOURT	Fast Fourier Transform.
GETANG	Calculates sun and observer angles with respect to the cloud normal.
GLINT	Calculates signal response due to solar glints.
HNO3	LOWEM Subroutine for $\text{HNO}_3$ extinction coefficients.
INTEG	Integration routine (trapezoidal rule).
INTER	Reads $J_p$ , $\tau_p$ , $\tau_o$ , $R_d$ and $H_s$ as a function of $\lambda$ and interpolates values needed for integration. Also interpolates cloud radiance.
LOWEM	Path transmission and radiance model (LOWTRAN IV).
POINT	LOWEM subroutine to interpolate absorber concentrations as a function of altitude.
SCALR	Scales array for printing.
SKYCLD	Calculates voltage response for sky and cloud background elements.



Table 2. (Continued)

<u>Subroutine</u>	<u>Purpose</u>
SUNLOC	Calculates sun location.
TGTSIG	Calculates target signature.
TRAJR	Calculates target position as a function of time.
 <u>Function</u>	
BLKBDY	Computes the blackbody emittance for a specified wavelength and temperature.
INTERP	Interpolates plume signature angular dependence.
NODD	Generates +1 or -1 depending on whether the function is even or odd.

Subroutine FIND. The sky/cloud spectral radiance data is stored in 5 files (see discussion of Subroutine SKYCLD and the model methodology in Section 2.4) as a function of the solar and view angles. The angles for the reflected solar and haze situations are:

solar angle ( $\theta_0$ )	:	0, 15, 30, 45, 60, 75, 85
relative azimuth angle ( $\phi$ )	:	0, 45, 90, 135, 180
view angle ( $\theta$ ), or	:	
supplement view angle ( $\theta'$ )	:	0, 15, 30, 45, 60, 75, 85

If we designate each spectral radiance data file ( $\lambda = 2, 3, 4, 5, 6, 8, 10$  and  $14 \mu\text{m}$ ) with a 3 parameter code corresponding to ( $\theta_0, \phi, \theta$ ), the data set (1, 3, 2) implies  $\theta_0 = 0^\circ$ ,  $\phi = 90^\circ$  and  $\theta = 15^\circ$ . If  $\theta_0 = 15^\circ$  and  $\phi = 150^\circ$  and  $\theta = 50^\circ$ , the desired data would lie somewhere between the (1, 4, 4) and (1, 5, 5) curves. This subroutine calculates the ratios between the two bounding curves through three successive calls from SKYCLD.

The angles for files 2 and 3 (transmission through 0.1 and 0.5 km thick clouds respectively) are:

azimuth angle ( $\phi$ )	:	0, 45, 90, 135, 180
view angle ( $\theta'$ )	:	0, 2, 4, 6, 8, 10

Here the solar angle ( $\theta_0$ ) is not explicitly used since the line-of-sight between the observer and the sun is the reference angle (see discussion of subroutine SKYCLD).

Subroutine FIX. This routine calls the fast Fourier transform and then reorders the transformed array. This re-ordering is necessary as the transform has been formulated for values on the interval (0, N-1) which yield 2 half periods back to back. It is necessary to move the origin to N/2 as shown in Figure 25 to ensure the peak of the transformed spectrum corresponds with the d.c. component of the transfer functions.

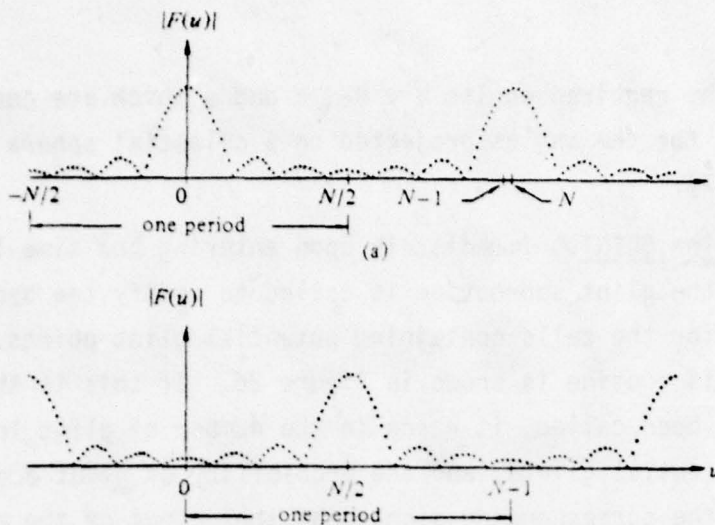


Figure 25. Shifting the Transformed Signal.

Subroutine FOURT. This subroutine performs the fast Fourier transform. The subroutine is being used with no modification. FOURT performs an  $n$ -dimensional fast Fourier transform on an  $n$ -dimensional array of complex data. The transform performed may be expressed as follows:  $\text{TRANSFORM}(J1, J2, \dots) = \text{SUM}(\text{DATA}(I1, I2, \dots) * W1^{**((I1-1)*(J1-1))} * W2^{**((I2-1)*(J2-1))} * \dots)$  where  $I1$  and  $J1$  run from 1 to the maximum of the first dimension,  $I2$  and  $J2$  run from 1 to the maximum of the second dimension. The basis of the routine was developed by Cooley and Tukey. The FORTRAN code being used was developed in 1965 at Sandia Corporation. The input data for the transform is assumed to be in the time domain and equally spaced at intervals of  $DT$ . The transformed values are considered to be in frequency space. The frequency intervals are equally spaced from 0 to  $2(N(I)-1)/(N(I)+DT)$  where  $N(I)$  is the dimension of the data (64) in each of the  $I$  dimensions (2). FOURT does not require the array to be a multiple of 2, but the computations are faster if this criteria is met. This routine was chosen because of its flexibility and computational speed. A two-dimensional transform of a  $64 \times 64$  array requires less than one second on the CDC 6600.

Subroutine GETANG. Once the sun's location has been established, subroutine GETANG then converts this information along with the observer's position into the cloud reference frame before calling the solar scatter



data table. The required angles are  $\theta_0$ ,  $\theta$  and  $\phi$  which are computed using the law of cosines for the angles projected on a celestial sphere (see Ref. 3 and Section 2.7).

Subroutine GLINT. Immediately upon entering the time loop in the main program, the glint subroutine is called to modify the background voltage array for the cells containing potential glint points. The flow diagram for this routine is shown in Figure 26. If this is the first time the subroutine has been called, it reads in the number of glint locations, the location of potential glints, and the probability of glint occurrence and then computes the corresponding signals at the output of the pre-amps due to each glint. If this is not the first time that the subroutine has been called, the signal levels computations are not repeated, and program control is transferred directly to the loop which calculates the random number for each glint point. If this random number exceeds the probability of glint occurrence the voltage for the cell under examination is modified by the precalculated glint voltage before program control is transferred back to the main program.

Subroutine INTER. This subroutine serves a dual purpose of reading the wavelength dependent data inputs and interpolating the data for the wavelength intervals required by the integration subroutine. IFLAG can take on values between 0 and 4 which in turn keys the routine to read the plume intensity, plume transmission, optical transmission, detectivity and solar irradiance inputs, respectively. Once this data has been read, the routine checks to see whether the specified wavelength interval for the passband of interest lies outside the minimum or maximum values specified by the inputs. If the wavelength of interest lies within the data bounds (as it should) YNEW is determined using a linear interpolation routine. IFLAG  $\geq 5$  allows for interpolation of the cloud/sky radiance tables. Figure 27 shows a logic flow for this subroutine.

Subroutine LOWEM. This subroutine is essentially LOWTRAN 3B with path emissions added. This program calculates the transmittance and irradiance of the atmosphere from 350 inverse centimeters to 40,000 inverse centimeters (0.25 to 28.5 microns) at 30 inverse centimeters spectral

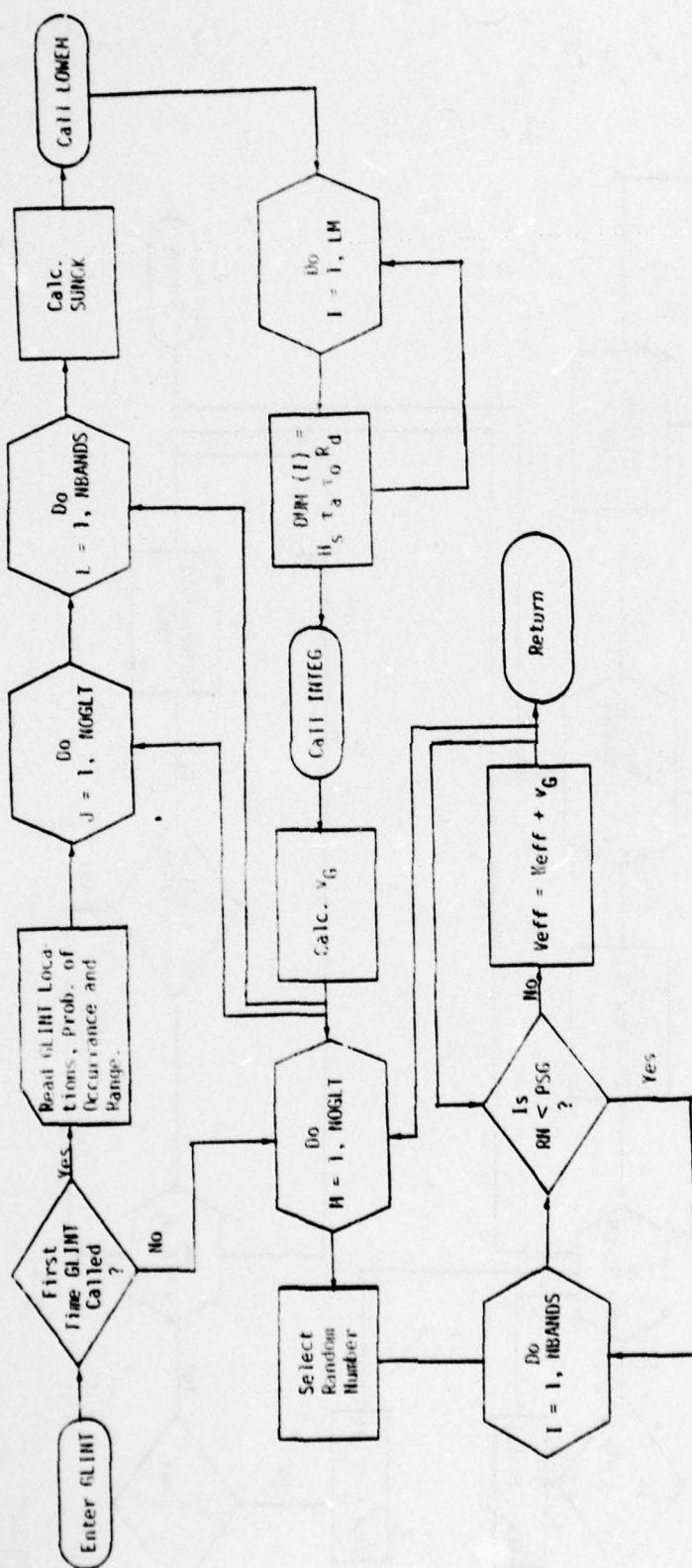


Figure 26. Flow Diagram for Subroutine GLINT.

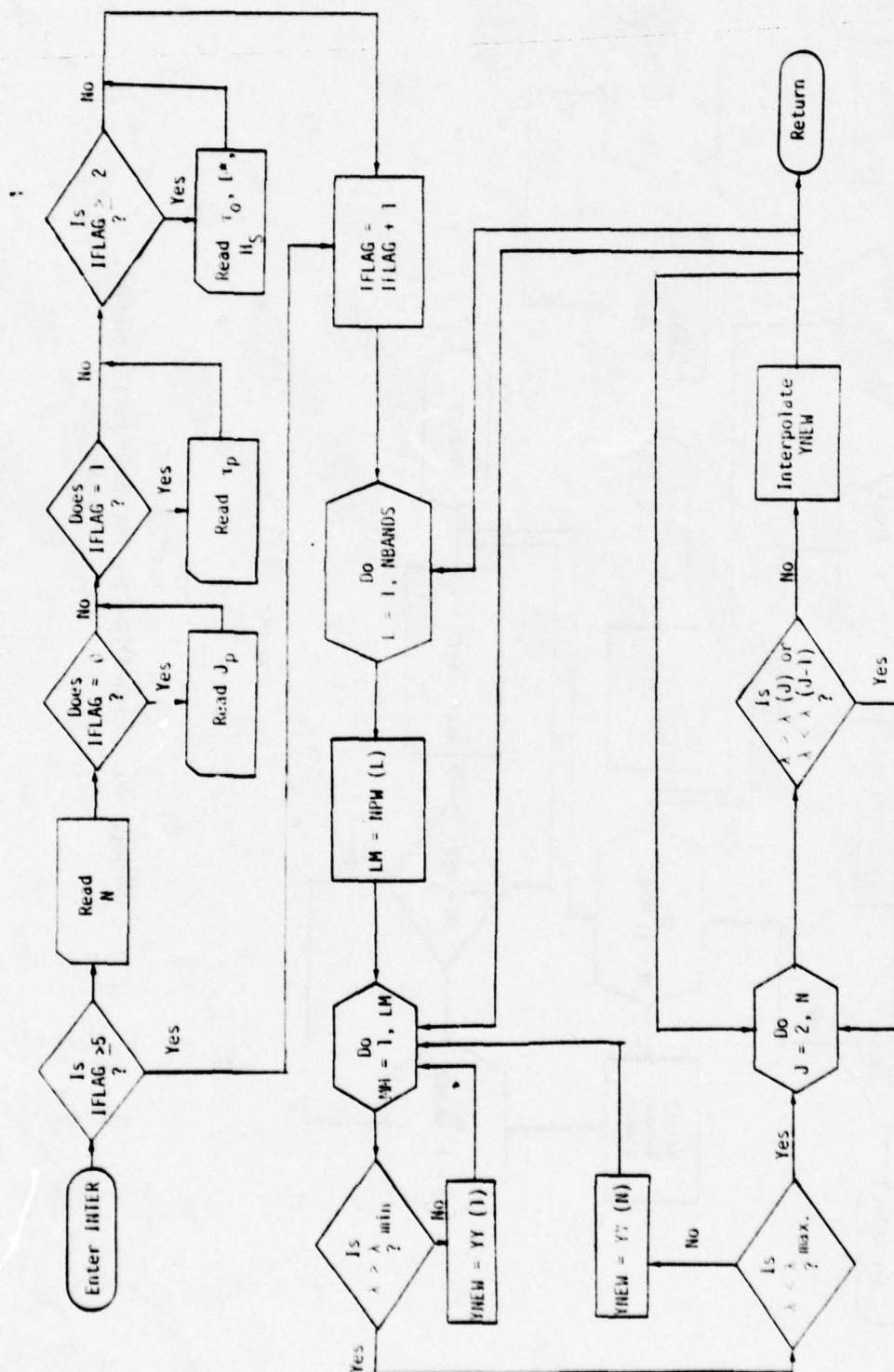


Figure 27. Flow Diagram for Subroutine INTER.



resolution on a linear wavenumber scale. Refraction and earth curvature effects are included. The atmosphere is layered in 1 kilometer intervals between 0 and 25 kilometers, 5 kilometer intervals to 50 kilometers, a 20 kilometer interval to 70 kilometers and a 30 kilometer interval to 100 kilometers. There are six model atmospheres available: tropical, mid-latitude summer, mid-latitude winter, sub-arctic summer, sub-arctic winter, and the 1962 U.S. Standard. The type of path is input using a code from 1 to 6 to select one of these atmospheres. It is also possible to input a new atmosphere such as radiosonde data in which case a seventh option would be indicated. Aerosol scattering can be computed and there is a haze model available.

There are three types of atmospheric paths - vertical or slant paths to space, vertical or slant paths between two altitudes, and a constant pressure path. The output of this subroutine is the path radiance and atmospheric transmission. Subroutine LOWEM requires Subroutine POINT which calculates the mean refractive index above and below a given altitude and interpolates exponentially to determine the equivalent absorber amount at that altitude. Also required for LOWEM is Subroutine ANGL which calculates the initial zenith angle, taking into account refraction effects.

Subroutine SCALR. This subroutine adjusts the magnitude of the voltage array to facilitate the evaluation of the computer printout. The minimum and maximum signal levels are first found. If the data is complex, the amplitude is used for finding the minimum and maximum. The minimum is then used to scale the data. A multiple of 10 is calculated such that when the data is multiplied/divided by this factor, the minimum does not exceed 100. Using the factor based on the minimum, the voltages are displayed.

Since the minimum is used, it is conceivable that the maximum value will exceed two digits, and the signal level will be displayed with an asterisk (\*). If this is the case, a new scale factor, based on the maximum, is used to scale the voltage array again. Glint points are ignored during these scaling calculations and are always displayed with asterisks.

Subroutine SKYCLD. Subroutine SKYCLD is one of the more complicated routines within IRSTEM. It is here that the signal response due to background sky and clouds are computed and substituted into the  $V_{eff}$  array (see Fig. 28). There are six types of sky conditions as indicated on Table 3. IC1 indicates a clear sky; this parameter keys the program to compute the path radiance only. IC2 and IC3 represent hazy conditions with 23 and 5 km visibility, respectively. These conditions vary from the clear sky computations in that solar scattering is added to path radiance. The last three types of sky conditions are clouds. The first two (100 m and 500 m clouds) represent the case when the observer is on the opposite side of the cloud from the sun and sees partial transmission as well as scattering and thermal radiation from the cloud. The last case (10 km cloud) models the back reflection from an optically thick cloud. Table 3 indicates the dimensions of the solar zenith angle (SZA) solar azimuth angle (AZA) and view angle (VA) which must be known to properly read the cloud radiance data that is on TAPE 8. The specific order of the data files is shown in the right hand column of Table 3.

The SKYCLD computations begin by calling the sun location subroutine to compute the azimuth and elevation angles of the sun. A series of angles are calculated next which are valid for all of the sky and cloud options except 10 km (reflective) cloud. It should be noted that the cloud normal is forced to coincide with the sun angle for all cases except the 10 km cloud to simplify the calculation of relative angles (see Figure 7). A series of flags are set before preceding into the signal response calculations to insure the proper sky and cloud radiance values are used. A detail flow diagram of the flag-setting algorithm is shown in Figure 29.

The initial step in setting the flags is to check to see if the clear sky conditions prevail; if so, the next few steps are bypassed and the calculations proceed as shown in Figure 28. Next a check is made to see if the 10 km thick cloud is specified; if so, the number of unique normals describing the cloud are read followed by the flags and data limits for TAPE 8. If neither IC1 nor IC6 are applicable, the subroutine DUMR is called to skip over the 10 km cloud file, and a check is made to see if the 100 m cloud is

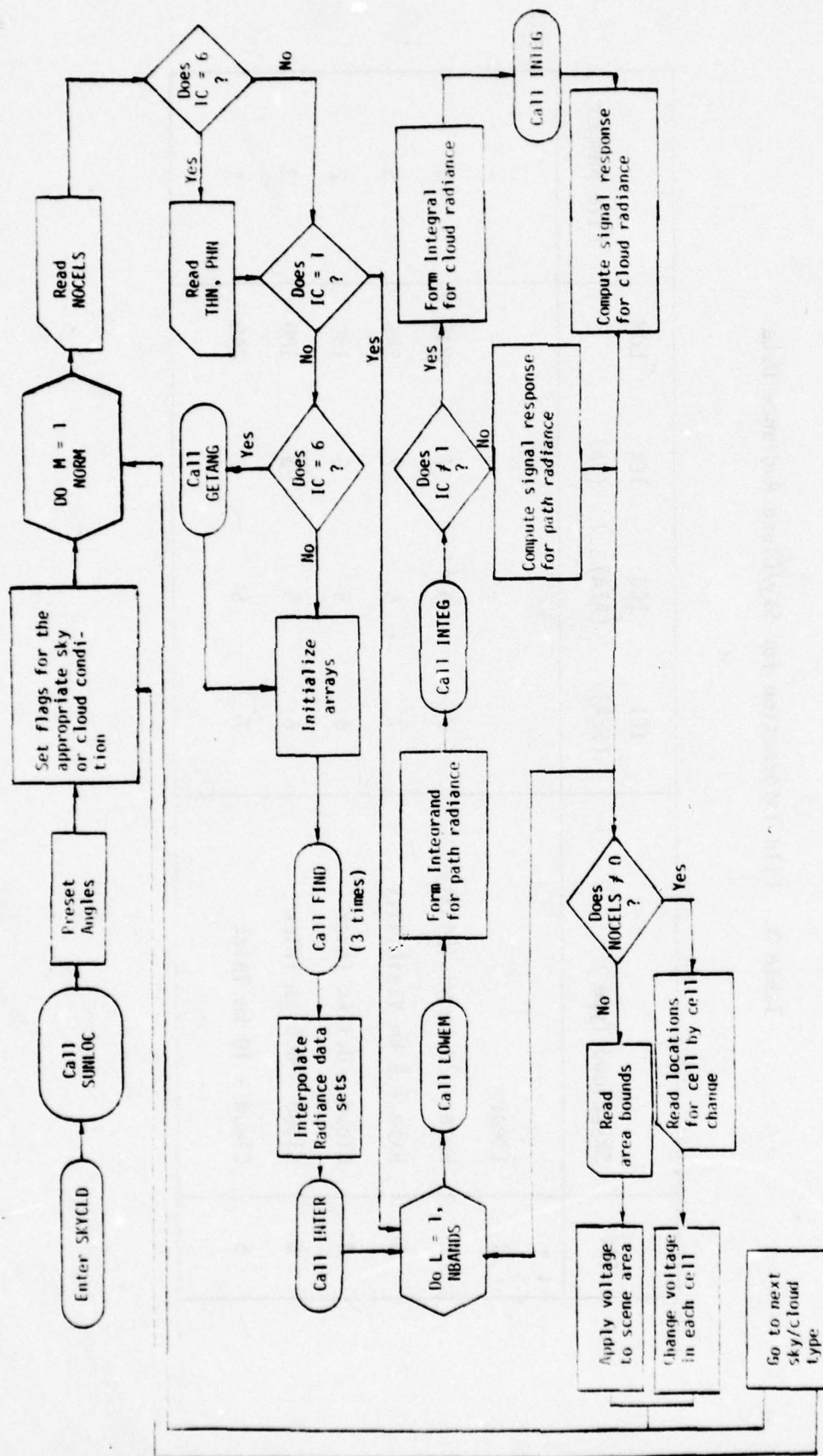


Figure 28. SKYCLD Flow Diagram.



Table 3. File Information for Sky/Cloud Radiance Data

ICi	Sky/Cloud Type	ICI (SZA)	ICJ (AZA)	ICK (VA)	LJM	File Number
i =						
1	Clear	-	-	-	-	-
2	Haze - 23 km Visibility	7	5	7	245	4
3	Haze - 5 km Visibility	7	5	7	245	5
4	Cloud - 0.1 km Thick	6	5	6	180	2
5	Cloud - 0.5 km Thick	6	5	6	180	3
6	Cloud - 10 km Thick	7	5	7	245	1

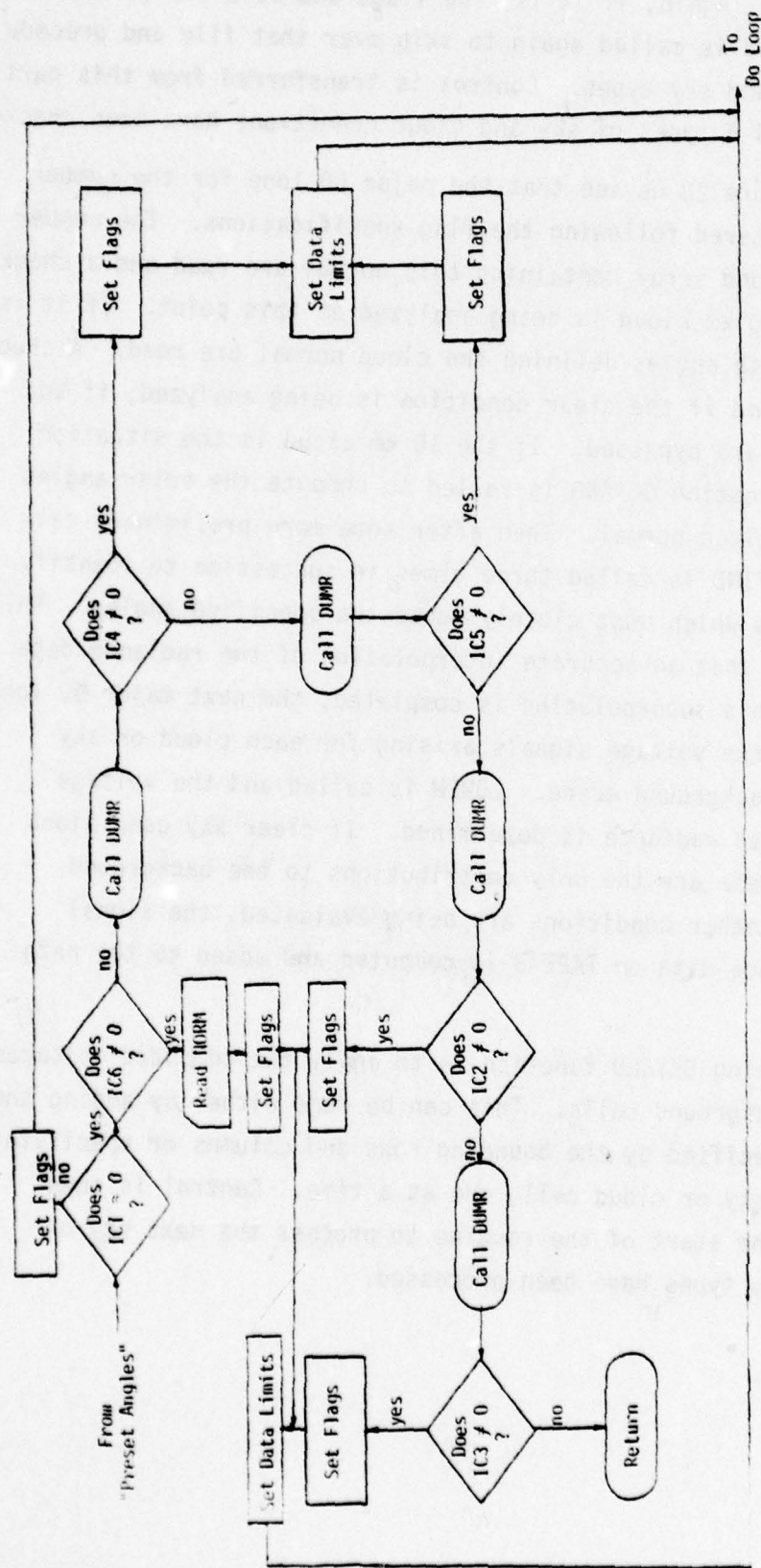


Figure 29. Flow Diagram for Setting Flags in SKYCLD.

now under consideration. Again, if it is, the flags and data limits are set; otherwise, the dummy read is called again to skip over that file and precede to the remaining cloud and sky types. Control is transferred from this part of the subroutine after all 6 types of sky and cloud conditions have been checked.

Returning to Figure 28 we see that the major DO loop for the number of unique normals is entered following the flag specifications. The number of cells of the background array containing this normal are read and a check is made to see if the 10 km cloud is being analyzed at this point. If it is, the elevation and azimuth angles defining the cloud normal are read. A check is then made to determine if the clear condition is being analyzed; if so, the next several steps are bypassed. If the 10 km cloud is the situation under examination, Subroutine GETANG is called to compute the solar angles in terms of the local cloud normal. Then after some more preliminary calculations, Subroutine FIND is called three times in succession to identify the radiance data files which most closely bound the specified angles. This is necessary to insure that an accurate interpolation of the radiance data tape is made. After this interpolation is completed, the next major DO loop is entered to compute the voltage signals arising for each cloud or sky condition within the background scene. LOWEM is called and the voltage contribution due to path radiance is determined. If clear sky conditions are being analyzed, these are the only contributions to the background signal level. If any other conditions are being evaluated, the signal response to the radiance data on TAPE 8 is computed and added to the path radiance.

The only remaining SKYCLD function is to apply the computed voltages to the appropriate background cells. This can be done either by adding the signals to an area specified by the bounding rows and columns or specifying the location of each sky or cloud cell, one at a time. Control is then transferred back to the start of the routine to process the next sky or cloud type until all 6 types have been processed.



The sequence of READ statements within SKYCLD are summarized in Table 4. The first time through the subroutine, checks are made for clear sky. If present, the number of cells which are clear and the minimum and maximum boundaries or the individual cell locations are read. On the next pass through the subroutine, a check is made to see if the 10 km cloud is present. If it is present, the number of cells with those normals, the defining angles for the cloud normal, and the cell locations are read. All of the rest of haze and thin cloud conditions are read in a manner similar to clear sky, in the sequence shown by the table.

Subroutine SUNLOC. The objective of SUNLOC is to calculate the altitude (vertical angle measured above the horizon) and true bearing (azimuth angle measured clockwise from true north) of the sun as a function of the geographical position of the observer (latitude and longitude), date (month, day), and time of day (Greenwich Mean Time). To develop a solution, one utilizes the celestial triangle as reviewed in references 1 and 3. The pertinent equations are specified in Section 2.7.

Subroutine TGTSIG. The target signature subroutine computes the total integrated intensity for each passband of interest and sums the projected areas of the overall missile. It begins by computing the projected areas of the tailpipe, nose and missile body. Then for each of the passbands, the tailpipe, missile nose, and missile body signatures are computed using the blackbody. The plume signature then is computed and all four terms are combined to give the overall radiant intensity. The equations used in this routine are summarized in Section 2.7.

Subroutine TRAJR. This subroutine locates the position of the target on the background with respect to an I, J index as well as the range from the sensor. Currently, this trajectory routine assumes that the target is a point source flying radially inbound with an aspect angle which does not change with time. Since these computations are in a separate subroutine, the trajectory information can be fed from an engagement simulator if desired.

Table 4. Read Sequence for SKYCLD\*

NOCELS	}	Clear Sky
ICMIN/MAX, JCMIN/MAX or NI(K), NJ(K)		
NORM	}	10 km Cloud
NOCELS		
THN, PHN		
ICMIN/MAX, JCMIN/MAX or NI(K), NJ(K)		
NOCELS	}	0.1 km cloud, 0.5 km cloud, 23 km haze and 5 km haze (in turn)
ICMIN/MAX, JCMIN/MAX or NI(K), NJ(K)		

\* Assuming all sky and cloud types are present  
in background scene

### 3.3 Subroutine Summary Tables

This subsection consists of tables summarizing the inputs and outputs of each subroutine. The first table (Table 5) is the cross-reference map of calls to each subroutine. Note that most of the calls come from either the main program, IRSTEM, or the SKYCLD subroutine. Tables 6 - 20 summarize the key parameters within each subroutine. Note that the column marked "location" identifies how the parameter is transferred to and from the subroutine. If a common block is used, its name appears in capital letters.



Table 5. Subroutine Call Reference Map

Subroutine/Function Used	Calling Program/Routine																			
	ANGL	DUMR	FIND	FIX	FOURT	GETANG	GLINT	HNO3	INTEG	INTER	LOWEM	NODD	POINT	SCALR	SKYCLD	SUNLOC	TGTSIG	TRAJR	BLKBDY	INTERP
IRSTEM				X				X			X	X	X	X	X	X	X	X	X	
ANGL																				
DUMR																				
FIND																				
FIX																				
FOURT																				
GETANG																				
GLINT																				
HNO3																				
INTEG																				
INTER																				
LOWEM																				
NODD																				
POINT																				
SCALR																				
SKYCLD																				
SUNLOC																				
TGTSIG																				
TRAJR																				
BLXBDY																				
INTERP																				

Table 6  
Subroutine FIND Parameters

<u>Input Parameter</u>	<u>Location</u>	<u>Description</u>
TH0	Call Statement	Desired $\theta_0$ , $\phi$ or $\theta$ on successive calls from SKYCLD (degrees).
ICI	Call Statement	Number of data entries.
SZA	Call Statement	Value of $\theta_0$ , $\phi$ or $\theta$ for which radiance data exists (degrees).
<u>Output Parameter</u>	<u>Location</u>	<u>Description</u>
J1	Call Statement	Data entry index for SZA immediately below TH0.
J2	Call Statement	Data entry index for SZA immediately above TH0.
D	Call Statement	Relative position of TH0 between SZA entries.

Table 7  
Subroutine FIX Parameters

<u>Input Parameter</u>	<u>Location</u>	<u>Description</u>
ISIGN	Call Statement	ISIGN equals 1 for an inverse transform ISIGN equals -1 for a for- ward transform
NUMBER	Call Statement	NUMBER equals 1 for a com- plex data; 0 for real data
U	Call Statement	Data to be transformed

<u>Output Parameter</u>	<u>Location</u>	<u>Description</u>
U	Call Statement	Transformed data



Table 8  
Subroutine FOURT Parameters

<u>Input Parameter</u>	<u>Location</u>	<u>Description</u>
DATA	Call Statement	Data to be transformed, corresponds to VARRY
NN	Call Statement	Dimension array describing the data dimensions, i.e., $NN(1) = 64$ , $NN(2) = 64$ , sets up a two-dimensional transform of $64 \times 64$ array
NDIM	Call Statement	The dimensionality of the transform, in this case, 2
ISIGN	Call Statement	Integer giving direction of transform to be done corresponds to ISIGN of Subroutine FIX
IFORM	Call Statement	Integer parameter describing the form of the data which corresponds to NUMBER of Subroutine FIX
WORK	Call Statement	Dummy variable or working array for the fast Fourier transform
<u>Output Parameter</u>	<u>Location</u>	<u>Description</u>
DATA	Formal Parameter	Transformed data is put back into the input data array

Table 9  
Subroutine GETANG

<u>Input Parameter</u>	<u>Location</u>	<u>Description</u>
ALT	ANG	Elevation angle of sun (rad).
PHL	GLT	True bearing of observer as seen from the cloud (rad).
PHN	ANG	True bearing of cloud normal (rad).
THL	GLT	Zenith angle of observer as seen from cloud (rad).
THN	ANG	Zenith angle of cloud normal (rad).
TRUEB	ANG	True bearing of sun (rad).
<u>Output Parameter</u>	<u>Location</u>	<u>Description</u>
TH	ANG	Angle of observer from cloud normal (rad).
THC	ANG	Angle of sun from cloud normal (rad).
PH	ANG	Angle between sun and observer in plane of cloud measured from reciprocal of the sun direction (rad).

Table 10  
Subroutine GLINT Parameters

<u>Input Parameter</u>	<u>Location</u>	<u>Description</u>
INIT	GLT	Flag = 0 until GLINT is called then = 1.
NOGLT	Card Read	Number of GLINT points.
PSG	Card Read	Probability that glint does not appear in a designated cell on the scan.
NG(I,1)	Card Read	Row number for glint I.
NG(I,2)	Card Read	Column number for glint I.
RGLINT(I)	Card Read	Range to glint I (m).
VEFF	GLT	Static voltage array (v).
<u>Output Parameter</u>	<u>Location</u>	<u>Description</u>
VEFF	GLT	Voltage array after glint is superimposed on a specified cell (v).



Table 11  
Subroutine INTEG Parameters

<u>Input Parameter</u>	<u>Type/Location</u>	<u>Description</u>
N	INTP	number of discrete points of the function
Y(300)	INTP	discrete points of the function to be integrated
WAVEL (100,3)	CONST	wavelength integration points
<u>Output Parameter</u>	<u>Type/Location</u>	<u>Description</u>
Y(1)	INTP	result of the integration.

Table 12  
Subroutine INTER Parameters

<u>Input Parameter</u>	<u>Location</u>	<u>Description</u>
IFLAG	INTP	flag specifying which spectral curve is being read and interpolated.
N	INTP	number of points to be read defining spectral curve.
NPW(3)	INTG	number of integration points in each curve for each given waveband.
WAVEL (100,3)	CONST	wavelength integration points.
XX (200)	Card Read	wavelengths defining the spectral curve.
YY (200)	Card Read	functional values at given wavelength values.
<u>Output Parameter</u>	<u>Location</u>	<u>Description</u>
YNEW (100,3)	INTP	interpolated values as a function of even inverse centimeter spacing

Table 13  
Subroutine LOWEM Parameters

<u>Input Parameter</u>	<u>Type/Location</u>	<u>Description</u>
MODEL	Call Statement	integer to select the model atmosphere: model 1 - tropical model 2 - mid-latitude summer model 3 - mid-latitude winter model 4 - sub-arctic summer model 5 - sub-arctic winter model 6 - 1962 U.S. Standard model 0 - horizontal path when meteorological data are used model 7 - new model atmosphere
IHAZE	Call Statement	integer to indicate aerosol attenuation IHAZE 0 - no aerosol attenuation IHAZE 1 - aerosol attenuation calculated.
ITYPE	Call Statement	integer to indicate the type of atmospheric path: ITYPE 3 - vertical or slant path to space ITYPE 2 - vertical or slant path between two altitudes ITYPE 1 - horizontal (constant pressure) path
LEN	Call Statement	LEN 1 - for a downward looking when two paths are possible (normally set to 0)
JP	Call Statement	print option
IM	Call Statement	IM 1 - for radiosonde data (normally set to 0)
M1, M2, M3	Call Statement	these integer values are used to change the temperature, the water and the ozone altitude profiles (normally set to 0)
ML	Call Statement	ML 1 - for radiosonde (normally set to 0)
IEMIS	Call Statement	integer to indicate mode of calculations: IEMIS 0 - transmission mode IEMIS 1 - radiance mode. (Always in IRSTEM.)



Table 13 (continued)

## Subroutine LOWEM Parameters

<u>Input Parameter</u>	<u>Type/Location</u>	<u>Description</u>
RO	Call Statement	range (km)
H1	Call Statement	height of observer in kilometers
H2	Call Statement	source altitude in kilometers
ANGLE	Call Statement	zenith angle at H1 in degrees
RANGE	Call Statement	pathlength in kilometers
BETA	Call Statement	earth center angle
VIS	Call Statement	visual range at sea-level in kilometers
WAVE1	Call Statement	lower bound of calculations in microns
WAVE2	Call Statement	upper bound of calculations in microns
DELAM	Call Statement	increment of calculations in microns
IXY	Call Statement	
ISP	Call Statement	integer to indicate previous calculations have been done: ISP 0 - indicates first call to Subroutine LOWEM ISP 1 - indicates more than one call to LOWEM
IWRITE	Call Statement	print FLAG
IJK	Call Statement	not used
ISTATE	Call Statement	not used
IAFLG	Call Statement	not used
TOTRAN	Call Statement	array names for transmission values
LW	Call Statement	dimension counter
NSAI	Call Statement	0 - Burch H <sub>2</sub> O model, 1 - White model
<u>Output Parameter</u>	<u>Type/Location</u>	<u>Description</u>
TAUA	LOW	transmissivity
APRA	LOW	path radiance

Table 14  
Subroutine SCALR

<u>Input Parameter</u>	<u>Location</u>	<u>Description</u>
EFF (64, 64, 1)	Call Statement	Signal response array (v)
IMAX	PRT	Number of rows in scene.
JMAX	PRT	Number of columns in scene
L	Call Statement	Waveband
LAVEL	Call Statement	Label for array printout
NG (40, 2)	PRT1	Location of glint points
NOGLT	PRT1	Number of glints
<u>Output Parameter</u>	<u>Location</u>	<u>Description</u>
IBK6 (64, 64)	PRT	Scaled background array.

Table 15  
Subroutine SKYCLD

<u>Input Parameter</u>	<u>Location</u>	<u>Description</u>
ALT	ANG	Elevation angle of sun (rad).
APR	LOW	Path radiance (mw/sr/cm <sup>2</sup> /μm).
AZA	Data Statement	Azimuth angle between sun and observer in cloud plane for which radiance values exist (rad).
D	MISC	Optics diameter (m)
DI, DJ, DK	Subroutine FIND	Relative position of TH0, PH and TH between the bounding data entries.
DUM (300) or YNEW (300)	INTP	Interpolated integrands for signal response calculations.
DV(3)	INTG	Wavelength interval (μm)
ELVS	ITRAJ	Zenith angle of sensor (rad).
I1, I2	Subroutine FIND	Data entry indices for SZA immediately below and above TH0.
IC1-IC6	GLT	Flags indicating the sky or cloud condition.
ICMIN, ICMAX	Card read	Rows bounding a given sky or cloud condition.
J1, J2	Subroutine FIND	Data entry indices for AZA immediately below and above PH.
JCMIN, JCMAX	Card read	Columns bounding a given sky or cloud condition.
K1, K2	Subroutine FIND	Data entry indices for VA immediately below and above TH.
NBANDS	INTG	Number of passbands.
NI(K), NJ(K)	Card Read	Row and column location of the K <sup>th</sup> cell of a given sky or cloud condition.
NOCELS	Card read	Number of background cells with a given normal.



Table 15 (Continued)

<u>Input Parameter</u>	<u>Location</u>	<u>Description</u>
NORM	Card Read	Number of unique normals for a given sky condition (set to 1 internally except for 10 km clouds).
PH	Internal calculation	Azimuth angle between sun and observer in cloud plane (rad) - from ANG only for 10 km cloud.
PHL	GLT	True bearing of line-of-sight (rad).
PHN	Card read	Azimuth angle of cloud normal (rad).
RB(40)	IMPT	Range to cloud (m)
RD		Responsivity (v/w)
SZA	Data statement	Solar zenith angle wrt cloud normal for which radiance data exists (rad).
TAUA	LOW	Atmospheric transmissivity.
TAUO	GLT	Optical Train Transmissivity.
TH	Internal calculation or ANG	View angle of observer wrt cloud normal (rad) from ANG only for 10 km cloud.
THN	Card read	Zenith angle of cloud normal (rad).
THO	Internal calculation or ANG	Solar zenith angle wrt cloud normal (rad) from ANG only for 10 km cloud.
TRUEB	ANG	True bearing of sun (rad).
VA	Data statement	Azimuth angle between sun and observer in cloud plane for which radiance values exist (rad).
XLAML(L),XLAM(U)	GLT	Upper and lower wavelengths for each waveband ( $\mu\text{m}$ ).
YR	Data statement or TAPE 8	Wavelengths for which radiance data exists on TAPE 8 ( $\mu\text{m}$ ) or the radiance values from the tape ( $\text{mw}/\text{sr}/\text{cm}^2/\mu\text{m}$ )

Table 16  
Subroutine SUNLOC

<u>Input Parameter</u>	<u>Location</u>	<u>Description</u>
MON	GLT	Month of year (1 - 12)
DAY	GLT	Day of month (1 - 31)
HR	GLT	Time of day (GMT).
RLAT	GLT	Latitude of interest (degrees) - North is +, South is - .
RLONG	GLT	Longitude of interest (degrees)

<u>Output Parameter</u>	<u>Location</u>	<u>Description</u>
ALT	ANG	Altitude of sun from horizon (rad)
TRUEB	ANG	True bearing of sun clockwise from True North (rad).

Table 17  
Subroutine TGTSIG

<u>Input Parameter</u>	<u>Location</u>	<u>Description</u>
ASPECT	ITRAJ	View angle of target wrt its center-line (degrees)
DP	MISS	Tailpipe diameter (m).
DT	ITRAJ	Target diameter (m).
ETE	MISS	Tailpipe emissivity.
ETN	MISS	Nose emissivity.
ETS	MISS	Skin emissivity.
TE	MISS	Tailpipe temperature ( $^{\circ}$ K)
TL	ITRAJ	Target length (m).
TN	MISS	Nose temperature ( $^{\circ}$ K).
TS	MISS	Skin temperature.
TJP (100, 3)	IMPT	Plume spectral intensity (w/m/ $\mu$ m)
TNL	MISS	Length of missile nose (m)
TGTAU (100, 3)	IMPT	Plume spectral transmissivity.
WAVEL (100, 3)	CONST	Wavelength of interest ( $\mu$ m)
<u>Ouput Parameter</u>	<u>Location</u>	<u>Description</u>
TJ	ITRAJ	Total target intensity (w/sr/ $\mu$ m)
AT	ITRAJ	Total target cross-section (m <sup>2</sup> )



Table 18  
Subroutine TRAJR Parameters

<u>Input Parameter</u>	<u>Type/Location</u>	<u>Description</u>
ELVS	ITRAJ	theta position of the sensor (rad)
IMAX	PRT	number of rows.
JMAX	PRT	number of columns.
PHITS	ITRAJ	azimuth position of the target (rad)
RS	ITRAJ	initial range of the target (m)
T	ITRAJ	engagement clock time (sec)
TF	ITRAJ	frame time (sec)
THTATS	ITRAJ	theta position of the target (rad).
VT	ITRAJ	velocity of the target (m/sec).

<u>Output Parameter</u>	<u>Type/Location</u>	<u>Description</u>
II	ITRAJ	I index position of target.
JJ	ITRAJ	J index position of the target
R	ITRAJ	range of the target.

Table 19  
Function BLKBDY

<u>Input Parameter</u>	<u>Location</u>	<u>Description</u>
C1	Call Statement	Constant = $3.713 \times 10^4$ ( $\text{W } \mu^4 \text{cm}^{-2}$ )
C2	Call Statement	Constant = $1.4388 \times 10^4$ ( $\mu^0 \text{K}$ )
TT	Call Statement	Temperature ( $^0 \text{K}$ )
XL	Call Statement	Wavelength ( $\mu$ )

<u>Output Parameter</u>	<u>Location</u>	<u>Description</u>
BLKBDY	Call Statement	Blackbody emittance ( $\text{W cm}^{-2} \mu^{-1}$ )

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Table 20  
Function INTERP

<u>Input Parameter</u>	<u>Location</u>	<u>Description</u>
ARG	Call Statement	Aspect angle (degrees).
N	Call Statement	Number of points defining plume intensity curve (nominally - 12)
X	Call Statement	Function describing the curve.
<u>Output Parameter</u>	<u>Location</u>	<u>Description</u>
Y	Call Statement	Function's value at the aspect angle of interest.

## Section 4

### USER'S INSTRUCTIONS

In this section code design information is provided to assist the IRSTEM user. The first part of this section reviews the input requirements and the output options. The key parameters used in the code are summarized on a table which includes the parameter, its symbol in the text and where it is defined, stored and used. This table combined with the List of Symbols and Subroutine Tables in Section 3 give a complete cross-reference for each of the major parameters. Finally, the section is completed with a sample program and test case.

#### 4.1 Inputs/Outputs

There are 36 sets of inputs required to operate IRSTEM, 33 formal inputs and three namelists. These inputs include a combination of tapes, formal input cards and namelists structured to provide maximum flexibility for the user. Some of the inputs are simply a single parameter while others are full arrays of many thousands of elements. There are no default options in IRSTEM; so the user must provide data for each of these inputs whenever the program is exercised.

Table 21 summarizes the input stream. All of the inputs are assumed to be cards or files of data in card image format unless otherwise noted as tapes or namelists. Each entry shows the requisite format, the calling routine (if other than the main program), the parameter's units and a description of each parameter including the flag options. The paragraphs below discuss these inputs, in turn, and provide additional information for the user beyond what is in the table.

Program operation begins by specifying the background array size and whether the debug option for additional printout is desired. It should be noted that in addition to specifying IMAX and JMAX, arrays other than 64 by 64 require the user to alter several dimension statements and common blocks. The required modifications are shown in Table 22. Most of the changes occur within the main program; however, five of the subroutines do require array

Table 21  
IRSTEM Inputs

Input 1 - 3I5

IMAX	-	Number of rows in background array.
JMAX	-	Number of columns in background array.
NBUG	-	0 → standard output 1 → expanded output

Input 2 - 5A6,I5 (Tape 1)

HOL	-	Title
MXCODE	-	Maximum number of different codes on the background tape.

Input 3 - 15I5 (Tape 1)

IBKG(I,J)	-	Array of background codes from 1 to IMAX and 1 to JMAX.
-----------	---	---

Input 4 - I5,4F10.3

KEY(I)	-	Integer value corresponding to background code.
TB(I)	$^{\circ}\text{K}$	Temperature for $I^{\text{th}}$ background code.
EB(I)	-	Emissivity for $I^{\text{th}}$ background code.
RHO(I)	-	Diffuse reflectivity for $I^{\text{th}}$ background code.
RB(I)	m	Range to $I^{\text{th}}$ background code.

Namelist SENSOR

XLAML(I)	$\mu\text{m}$	Lower bound of the wavebands of interest } $I = 2,3$
XLAMU(I)	$\mu\text{m}$	
TF	sec	Scan time
D	m	Diameter of the optics
DX	m	Width of the detector
DY	m	Length of the detector
OVL	m	Amount of overlap between detectors.
FL	m	Focal length
FO	hz	Cutoff frequency
ELVS	degrees	Elevation angle of the background
VNOISE	v	RMS noise level
RDPK	v/w	Peak responsivity
DSTRPK	$\text{cm hz}^{\frac{1}{2}} \text{w}^{-1}$	$D^*$ or detectivity



Table 21 (Continued)

## IRSTEM Inputs

Input 5 - 2I5, 2E10.3, A8

MODET	-	Type of trajectory, trajectory mode (not used)
NBANDS	-	Number of wavebands to be considered (1, 2 or 3)
XLAML(1)	$\mu\text{m}$	Lower bound of first waveband
XLAMU(1)	$\mu\text{m}$	Upper bound of first waveband
NAMET	-	Name of the target.

Input 6 - 4I5, 4F10.3, I5

MODEL	-	Integer code for type of atmosphere (see Table 13)
IHAZE	-	Integer to indicate if aerosol scattering is to be used (0=no aerosol, 1=aerosols included)
ITYPE	-	Type of atmospheric path (see Table 13)
IEMIS	-	Mode code to indicate transmittance or radiance (must be 1 if path radiance is to be included)
HS	m	Observer altitude
DV(I)	$\mu\text{m}$	Integration intervals ( $I=1, \text{NBANDS}$ )
NSAI	-	NSAI=1 indicates that White water vapor continuum is to be used in place of the Burch model.

Input 7 - I5 from INTER

N	-	Number of $(\lambda, J_p)$ pairs
---	---	----------------------------------

Input 8 - 4(F12.3,E8.2) from INTER

$\lambda(I)$	$\mu\text{m}$	Wavelength	} $I = 1, N$
TJP(I)	w/sr/ $\mu\text{m}$	Target plume intensity	

Input 9 - I5 from INTER

N	-	Number of $(\lambda, \tau_p)$ pairs
---	---	-------------------------------------

Input 10 - 9XF7.4, 52XF6.4 from INTER

$\lambda(I)$	$\mu\text{m}$	Wavelength	} $I = 1, N$
TGTAU(I)	-	Plume transmission	

Input 11 - I5 from INTER

N	-	Number of $(\lambda, \tau_o)$ pairs
---	---	-------------------------------------

Table 21 (Continued)

IRSTEM Inputs

Input 12 - SF10.3 from INTER

$\lambda(I)$	$\mu m$	Wavelength	} $I = 1, N$
TAUO(I)	-	Optical Transmission	

Input 13 - I5 from INTER

N	-	Number of $(\lambda, D^*)$ pairs
---	---	----------------------------------

Input 14 - SF10.3 from INTER

$\lambda(I)$	$\mu m$	Wavelength	} $I = 1, N$
$D^*(I)$	$cm \cdot Hz^{1/2} \cdot W^{-1}$	Detectivity	

Input 15 - I5 from INTER

N	-	Number of $(\lambda, H_s)$ pairs
---	---	----------------------------------

Input 16 - SF10.3 from INTER

$\lambda(I)$	$\mu m$	Wavelength	} $I = 1, N$
SR(I)	$W/cm^2$	Solar irradiance at earth's surface	

Namelist TRAJ

RS	m	Initial range of target
TV	m/sec	Velocity of target
DT	m	Diameter of target
TL	m	Length of target body
THTATS	degrees	Elevation of target
PHITS	degrees	Azimuth of target
TNL	m	Length of Nose
TPL	m	Plume Length (not used at this time)
DP	m	Diameter of the exhaust pipe
TE	$^{\circ}K$	Temperature of exhaust
TN	$^{\circ}K$	Temperature of the nose
TS	$^{\circ}K$	Temperature of the body of the missile

Table 21 (Continued)

## IRSTEM Inputs

Namelist TRAJ (Continued)

ETN	-	Emissivity of the nose
ETS	-	Emissivity of the body of the target
ETE	-	Emissivity of the exhaust
ASPECT	degrees	Aspect angle of the target relative to the line of sight
TMAX	sec	Maximum time of the encounter

Namelist SUN

RLAT	degrees	Latitude of the observer
RLONG	degrees	Longitude of the observer
MON	-	Month (1-12)
DAY	-	Day (1-31)
HR	-	Hour of the day (GMT)
PHL	degrees	Locates the observer with respect to true North in a counterclockwise direction as seen from the target

Input 17 - I5 from SKYCLD

NOCELS	-	Number of cells with clear sky (Flag for Input 18. If NOCELS=0, block data is read)
--------	---	---

Input 18 - 16I5 from SKYCLD

ICMIN	-	} Row limits for clear sky
ICMAX	-	
JCMIN	-	} Column limits for clear sky
JCMAX	-	
or		

Input 18 - 16I5 from SKYCLD

NI(K)	} K = 1, NOCELS	Cell by cell specification of clear sky positions
NJ(K)		

Input 19 - I5 from SKYCLD

NORM	-	Number of unique normals for 10 km thick cloud.
------	---	---



Table 21 (Continued)

IRSTEM Inputs

Input 20 - 15 from SKYCLD

NOCELS                    -                    Number of cells with 10 km thick cloud.

Input 21 - 2E10.3 from SKYCLD

THN                    degrees                    Zenith angle of cloud normal

PHN                    degrees                    Azimuth angle of cloud normal

Input 22 - 1615 from SKYCLD

Same as Input 18 for 10 km thick cloud

Input 23

Input 24

} Same as Inputs 17 and 18 for 0.1 km thick cloud

Input 25

Input 26

} Same as Inputs 17 and 18 for 0.5 km thick cloud

Input 27

Input 28

} Same as Inputs 17 and 18 for 23 km haze

Input 29

Input 30

} Same as Inputs 17 and 18 for 5 km haze

Input 31 - 15, E10.3 from GLINT

NOGLT                    -                    Number of cells with potential glints

PSG                    -                    Probability that a glint will not occur on any given scan.

Input 32 - 1615 from GLINT

NG(I,1)

NG(I,2)

} I = 1, NOGLT

Row position of 1<sup>th</sup> glint

Column position of 1<sup>th</sup> glint

Input 33 - 8E10.3 from GLINT

RGLNT(I)                    m                    Range to each glint point

I=1, NOGLT

Table 22  
Changes Required if IMAX or JMAX Do Not Equal 64

Dimension Statements	Dimension	IRSTEM	Subroutines					
			FIX	GETANG	GLINT	SCALR	SKYCLD	SUNLOC
VARRAY	64,64,6	X						
IBKG	64,64	X				X		
TVEFF	64,64,3	X						
H	64,64,3	X						
V	64,64,6	X						
EFF	64,64,3	X						
U	64,64		X			X		
Common Blocks								
GLT (VEFF)	64,64,3	X		X	X		X	X
PRT (IBKG)	64,64		X					

modifications before the program will function properly. To make the modifications, the user changes the array dimension from 64 to the appropriate number. It is not required that this number be a multiple of 2, but the Fast Fourier Transform will operate more efficiently if it is a multiple of 2.

Inputs 2, 3 and 4 define the background. After the header information is provided, the background codes (one for each cell) are read as Input 3. Then key cards are read (one for each background type) to associate each code with the desired temperature, emissivity, reflectivity and range.

The next 3 sets of inputs provide information about the sensor and the atmospheric conditions desired for the engagement. These inputs are fixed parameters that do not vary with wavelength. Namelist Sensor provides information on the hardware design and Input 6 is a shortened LOWTRAN input list required by LOWEM. The rest of the LOWEM parameters are shown in the subroutine table (Table 13). These parameters are set to default values internally in the program.

Inputs 7 through 16 are the spectrally dependent parameters which must be read in the order shown. Two sets of inputs are needed for each parameter. The first card specifies the number of data points and the remaining cards give the wavelength and corresponding value of the functional for each data point. These inputs are called from Subroutine INTER which then interpolates the function as required for the integration subroutine. Two additional namelists follow Input 16. The first is used to describe the engagement dynamics and inputs required for the target signature calculation (Namelist TRAJ). The second specifies the location of the engagement with parameters necessary to compute the sun's location (Namelist SUN).

Inputs 17 through 30 are associated with the cloud radiance model. The cloud inputs must, of course, be correlated with the background data read at the start of the program; however, these cards give the user the flexibility of creating any type of cloud or clear/haze air conditions he wishes. The required read sequence is clear sky, 10 km thick clouds, 0.1 km thick clouds, 0.5 km thick clouds, 23 km haze and finally 5 km haze if present in the background description. In general, there are two inputs required for each sky/cloud condition. The first is the number of cells whose location will be individually specified as containing this sky or



cloud condition. The next input then specifies the location of these cells. If the sky/cloud condition can be conveniently described as a rectangular section, the user has the option of specifying the bounds of the rectangle instead of specifying the location of individual cells. However, the user cannot specify a combination of area and individual cell locations. The above read sequences are valid for all the sky and cloud conditions with the exception of the 10 km, reflective cloud. Here, the first input is the number of unique cloud normals used to describe the cloud. Then the number of cells with those normals are given and defined by their zenith and azimuth angles. Finally, the location of these cells are read in the same manner as before (i.e., by block areas or individual cell locations). Inputs 20 through 22 are repeated then for each of the normals specified in Input 19.

The final three inputs are associated with the sun glint computations. Input 31 identifies the number of cells containing potential sun glints and the probability with which the sun glints will occur. Note that this probability is applied equally to all glints. Next, each glint location must be specified on a cell-by-cell basis (there is no option for specifying sun glint areas at this time). Finally the range associated with each of the sun glints is specified. Normally this range will correspond to the background range given in Input 4.

The IRSTEM outputs are summarized in Table 23 which shows the parameter in the order of its appearance. Parameters which are preceded with an asterisk indicate debug options which are printed only if NBUG > 0.

The output sequence generally follows the input sequence with the background conditions specified first followed by descriptions of the sensor, target and environmental conditions. Note that when Namelist SENSOR is printed, the wavelength values for the primary band are not repeated since they are shown at the beginning of the output listing. The outputs which are printed on each iteration of the time loop are (1) the total projected area at that time, (2) the target's range and (3) the response voltage of the target cell for each waveband. The signal response from each detector,  $V_n(t)$ , is recorded on Tape 12 for later signal processing analysis but is not printed. To more fully understand the output sequence and format, the reader should examine the sample output given at the end of this section.

Table 23  
IRSTEM Outputs

<u>Parameter</u>	<u>Units</u>	<u>Description</u>
IMAX, JMAX	-	Number of rows and columns in background array.
HOL		Title
KEY(I)		} Descriptors for each background code.
TB(I)	°K	
EB(I)		
RHO(I)		
RB(I)	m	
*IBKG(I,J)	-	Input background array
Input 5		} Target information and passbands
XLAML(J)	{ J=2,    μm NBANDS    μm	
XLAMU(J)		
Input 6		LOWEM inputs
Namelist SENSOR		
$\tau_0(\lambda)$	-	} Spectrally dependent inputs.
$D^*(\lambda)$	cm hz <sup>1/2</sup> w <sup>-1</sup>	
$R_d(\lambda)$	v/w	
$H_s(\lambda)$	w/cm <sup>2</sup>	
Namelist TRAJ		
Namelist SUN		
*IBKG(I,J)	-	Background array with sequenced numbers.
*VEFF(I,J,L)	v	Signal response to static scene and sunglints.
*J <sub>TP</sub> (λ)		} Target signature including component parts
J <sub>N</sub> (λ)		
J <sub>S</sub> (λ)	w/sr/μm	
J <sub>P</sub> (λ)		
J <sub>T</sub> (λ)		

Table 23 (Continued)  
IRSTEM Outputs

<u>Parameters</u>	<u>Units</u>	<u>Description</u>
*A <sub>N</sub>	} m <sup>2</sup>	Projected target areas.
A <sub>S</sub>		
A <sub>E</sub>		
A <sub>T</sub>		
T	sec	
A <sub>T</sub>	m <sup>2</sup>	
*VEFF(I,J,L)	v	Scaled scene response.
*TVEFF		Scaled transformed array.
R	m	} Target status presented for each iteration of the time loop.
VEFF(L)	v	
*EFF	v	Scaled scene array after the sensor distortions are added.
v <sub>n</sub>	v	Final signal response for each of the detectors is written on TAPE 12.



#### 4.2 Parameter List

A List of Symbols is given in the front of this report identifying the symbols used in the theory section. In Section 3.2 a series of tables (Tables 6 through 20) are provided summarizing the inputs and outputs associated with each of the subroutines and in Section 4.1 above, the inputs and outputs required to operate the code are identified. In this subsection the cross-references for the key parameters is completed by identifying each of the important code symbols as they appear in IRSTEM in alphabetical order.

Each of these key parameters are listed on Table 24 which includes the corresponding report symbol, its units, where the symbol is defined, its common block, and which are the primary routines in IRSTEM in which it is used. Under the "Defined" column there are four options. Words which appear in all caps (such as SUNLOC) indicate the parameter is defined in a subroutine. If the word begins with a capital letter (such as Sensor), this indicates a namelist read. Formal read inputs are indicated as Input x and are based on the read sequence shown in Table 21. Finally, some of the parameters are defined in data blocks. The dimensions of the variables are given in the "Description" column where applicable, and if the array is a complex one, this also is noted.

Table 24  
Parameter List

Parameter		Units	Defined	Common Block	Primary Routines	Description
Code	Report					
AE	AE	m <sup>2</sup>	TGTSIG	-	TGTSIG	Projected area of tailpipe.
ALT	$\theta_{ALT}$	rad	SUNLOC	ANG	FIND	Elevation of sun above horizon.
AN	A <sub>N</sub>	m <sup>2</sup>	TGTSIG	-	TGTSIG	Projected area of missile nose.
ANGLE	$\xi$	degrees	Data Block	POST	IRSTEM TRAJR	(12) Angles defining relative plume strength.
APR	N <sub>A</sub>	mm/str-cm <sup>2</sup>	LOWEM	LOW	IRSTEM LOWEM TRAJR SKYCLO	(100) Path radiance
ARG	ASPECT	degrees	TGTSIG	-	INTERP	Aspect angle of missile.
AS	A <sub>S</sub>	m <sup>2</sup>	TGTSIG	-	TGTSIG	Projected area of missile fuselage.
ASPECT	$\xi$		Traj	ITRAJ	TRAJR	Angle between target centerline and sensor line-of-sight.
AT	-	m <sup>2</sup>	TGTSIG	ITRAJ	TRAJR	Total projected target area.
AZA	$\phi$	degrees	Data Block	-	SKYCLO	(2,7) Solar azimuth angle wrt cloud normal defining sky/cloud radiance data.
BL	$\nu_L$	cm <sup>-1</sup>	IRSTEM	INTG	IRSTEM	(3) Lower bound of passband.
BLKBDY	W	w/cm <sup>2</sup> /μm	BLKBDY	-	IRSTEM TGTSIG	Blackbody emittance.
BU	$\nu_U$	cm <sup>-1</sup>	IRSTEM	INTG	IRSTEM INTEG	(3) Upper bound of passband.
CV	$\Delta\nu$	cm <sup>-1</sup>	IRSTEM	INTG	IRSTEM	Wavenumber increment size.

Table 24 (Continued)

Parameter		Units	Defined	Common Block	Primary Routines	Description
Code	Report					
D	D	m	Sensor	MISC	IRSTEM	Optics diameter.
DAY	-	-	Sun	GLT	SUNLOC	Day of the month (1-31)
DEGRAD	-	-	IRSTEM	MISC	Most Routines	$\pi/180$
DP	-	m	Traj	MISS	TGTSIG	Tailpipe diameter.
DSTRPK	$D^*_{\text{peak}}$	$\text{cm hz}^{1/2} \text{w}^{-1}$	Sensor	-	IRSTEM	Peak detectivity.
DT	$D_T$	m	Traj	ITRAJ	TGTSIG	Target diameter.
DUM	-	-	IRSTEM	INTP	IRSTEM	(300) Dummy array for spectral integrations.
DV	$\Delta\lambda$	$\mu\text{m}$	Input	INTG	IRSTEM SKYCLOD	Wavelength increment for LOWEM
DX	$L_x$	m	Sensor	-	IRSTEM	Detector dimension in scan direction.
DY	$L_y$	m	Sensor	-	IRSTEM	Detector dimension orthogonal to scan.
EG	$\epsilon_B$	-	Input	IMPT	IRSTEM	(40) Background emissivity.
EFF	$V_{\text{eff}}$	v	IRSTEM	-	IRSTEM SCALR	(64, 64, 3) Complex voltage array after transfer functions are added.
ELVS	$\theta_E$	degrees	Sensor	ITRAJ	TGTSIG	Elevation of scene centroid measured from zenith (converted to radians internally).
ETE	-	-	Traj	MISS	TGTSIG	Tailpipe emissivity.
ETN	$\epsilon_H$	-	Traj	MISS	TGTSIG	Missile nose emissivity.



Table 24 (Continued)

Parameter		Units	Defined	Common Block	Primary Routines	Description
Code	Report					
ETS	$E_S$	-	Traj	MISS	TGTSIG	Missile skin emissivity.
FL	F	m	Sensor	-	IRSTEM	Focal length.
F0	$f_0$	hz	Sensor	-	IRSTEM	Electronics cutoff frequency.
FUNC	$f_p$	-	Data Block	-	INTERP	(12) Plume strength as a function of aspect angle.
H	-	-	IRSTEM	GLT	IRSTEM	(64, 64, 3) Complex-Modified transform array.
HR	-	-	Sun	GLT	SUNLOC	Greenwich mean time (1-24)
HS	-	m	Input 6	CONST	LOWEM	IRST Altitude.
H1	-	km	IRSTEM	MISC	LOWEM	Height of observer (IRST).
H2	-	km	IRSTEM	MISC	LOWEM	Height of target.
I1,I2	-	-	FIND	-	SKYCLO	Data entry indices for SZA immediately below and above TH0.
IBKG	-	-	Input 3	PRT	IRSTEM SCALP	(64, 64) Initial background code and normalized code; also used an output array for SCALP.
IC	-	-	SKYCLO	-	SKYCLO	Flag set to 1,2...to represent IC1, IC2...IC6.
IC1	-	-	SKYCLO	-	FIND	Flag indicating number of solar zenith angle points in cloud radiance data (see Table 3).
IC2	-	-	SKYCLO	-	FIND	Flag indicating number of solar azimuth angle points (see Table 3)

Table 24 (Continued)

Parameter		Units	Defined	Common Block	Primary Routines	Description
Code	Report					
ICK	-	-	SKYCLO	-	FIND	Flag indicating number of view angle points (see Table 3).
ICMIN, ICMAX	-	-	Input 18	-	SKYCLO	Rows bounding a given sky or cloud condition.
IC1	-	-	IRSTEM	GLT	IRSTEM SKYCLO	Flag indicating clear sky.
IC2	-	-	IRSTEM	GLT	IRSTEM SKYCLO	Flag indicating 23 km visibility.
IC3	-	-	IRSTEM	GLT	IRSTEM SKYCLO	Flag indicating 5 km visibility.
IC4	-	-	IRSTEM	GLT	IRSTEM SKYCLO	Flag indicating 0.1 km cloud transmission.
IC5	-	-	IRSTEM	GLT	IRSTEM SKYCLO	Flag indicating 0.5 km cloud transmission.
IC6	-	-	IRSTEM	GLT	IRSTEM SKYCLO	Flag indicating 10 km cloud reflection.
IEMIS	-	-	Input 6	CONST	LOWEM	Mode code to indicate transmittance or radiance (must = 1).
IERROR	-	-	TRAJR	ITRAJR	IRSTEM TRAJR	Flag indicating target is outside bounds of the scene.
IFLAG	-	-	INTER	INTP	INTER	Flag specifying which spectral curve is being read and interpolated.
IHAZE	-	-	Input 6	CONST	LOWEM	Flat to indicate if aerosol scattering is to be used.
II	-	-	TRAJR	ITPAJ	IRSTEM	Row in which target is located.

Table 24 (Continued)

Parameter		Units	Defined	Common Block	Primary Routines	Description
Code	Report					
IMAX	-	-	Input 1	PRT	IRSTEM TRAJR	Number of rows.
INIT	-	-	GLINT	GLT	GLINT	INIT = 0 until GLINT is called the first time.
ITYPE	-	-	Input 6	CONST	LOWEM	Type of atmospheric path
IZ1-IZ2	-	-	Data Block	REST	LOWEM	LOWEM call parameter (= 0)
J1, J2	-	-	FIND	-	SKYCLO	Data entry indices for AZA immediately below and above PH.
JCMIN, JCMAX	-	-	Input 18	-	SKYCLO	Columns bounding a given sky or cloud condition.
JJ	-	-	TRAJR	ITRAJ	IRSTEM	Column in which target is located.
JMAX	-	-	Input 1	PRT	IRSTEM	Number of columns.
K1, K2	-	-	FIND	-	SKYCLO	Data entry indices for VA immediately below and above TH.
KEY	-	-	Input 4	IMPT	IRSTEM	(40) Background key index.
KK	-	-	SKYCLO	-	SKYCLO	Set to IC1-IC6 respectively.
L	-	-	Most routines	-	Most routines	Waveband flag (= 1,2,3)
LAVEL	-	-	SCALR	-	SCALR	(16) Label for array printout.
LJM	-	-	SKYCLO	-	SKYCLO	Product of IC1, ICJ and ICK.
LM	-	-	IRSTEM	INTP	INTER	Number of points to be interpolated.



Table 24 (Continued)

Parameter		Units	Defined	Common Block	Primary Routines	Description
Code	Report					
MODEL	-	-	Input 6	CONST	LOWEM	Integer to select model atmosphere.
MODET	-	-	Input 5	ITRAJ	-	Type of trajectory (not used currently).
MON	-	-	Sun	GLT	SUNLOC	Month (1-12).
N	-	-	Input 7	-	INTER	Number of spectral curve points to be read.
NBANDS	-	-	Input 5	INTG	Most routines	Number of passbands.
NBUG	-	-	Input 1	GLT	IRSTEM SKYCLD	Debug flag for extra printouts.
NG	-	-	Input 32	-	GLINT	(40,2) Glint position: NG(#,1) - row NG(#,2) - column
NI(K)	-	-	Input 18	-	SKYCLD	(8) Row location of the K <sup>th</sup> cell of a given sky or cloud condition.
NJ(K)	-	-	Input 18	-	SKYCLD	(8) Column location of the K <sup>th</sup> cell of a given sky or cloud condition.
NOCELS	-	-	Input 17	-	SKYCLD	Number of background cells with a given normal.
NOGLT	-	-	Input 31	-	GLINT SCALR	Number of glint points.
NORM	-	-	Input 19	-	SKYCLD	Number of unique normals for 10 km thick cloud.

Table 24 (Continued)

Parameter		Units	Defined	Common Block	Primary Routines	Description
Code	Report					
NPW	-	-	IRSTEM	INTG	INTER	(3) Number of intergration points to be interpolated for each waveband.
NSAI	-	-	Input 6	CONST	LOWEM	Flag indicating use of Burch (NSAI=0) or White (NSAI=1) water vapor model.
OVL	OVL	m	Sensor	-	IRSTEM	Amount of overlap between detectors.
PH	$\phi$	rad	GETANG	ANG	FIND SKYCLOD	Azimuth angle between sun and observer in plane of cloud wrt reciprocal of sun direction.
PHITS	$\phi_{TS}$	degrees	TraJ	ITRAJ	TRAJR	Azimuth position of target (converted to radians internally).
PHL	$\phi_{TB}$	degrees	Sun	GLT	GETANG SKYCLOD	True bearing of observer.
PHN	$\phi_N$	rad	Input 21	ANG	GETANG SKYCLOD	True bearing of cloud normal.
PI	$\pi$	-	IRSTEM	MISC	Many	3.14159265
PSG	-	-	Input 31	-	GLINT	Probability of no sunglint on any given scan.
R	R	m	TRAJR	ITRAJ	IRSTEM	Target's instantaneous range.
RB	$R_B$	m	Input 4	IMPT	IRSTEM SKYCLOD	(40) Range to background.
RD	$R_d$	v/w/ $\mu m$	IRSTEM	GLT	GLINT IIRSTEM SKYCLOD	(100,3) Spectral responsivity

Table 24 (Continued)

Parameter		Units	Defined	Common Block	Primary Routines	Description
Code	Report					
RDPK	$(R_d)_{\text{peak}}$	v/w	Sensor	-	IRSTEM	Peak responsivity.
RGLNT	$R_g$	m	Input 33	-	GLINT	(40,2) Range to glint.
RHO	$\rho$	-	Input 4	IMPT	IRSTEM	(40) Background diffuse reflectivity.
RLAT	Lat	degrees	Sun	GLT	SUNLOC	Latitude (North is +, South is -).
RLONG	-	degrees	Sun	GLT	SUNLOC	Longitude.
RN	RN	-	Data Block	-	IRSTEM	(299) Random numbers.
RS	-	m	Traj	ITRAJ	TRAJR	Starting range of target.
RZ1-RZ4	-	m	Data Block	PEST	LOWEM	Lowtran parameters (=0).
SR	$H_s$	w/cm <sup>2</sup>	Input 16	IMPT	GLINT IRSTEM	(100,3) Solar irradiance at earth's surface.
SZA	$\theta_0$	degrees	Data Block	-	FIND SKYCLOD	(2,7) Solar zenith angle wrt cloud normal defining sky/cloud radiance data.
T	t	sec	TRAJR	ITRAJ	IRSTEM TRAJR	Current time (t=0 at program start)
TAPE1	-	-	Input 3	-	IRSTEM	Background code input.
TAPE3	-	-	Input 3	-	LOWEM	LOWEM Input (=Tape 5)
TAPE5	-	-	-	-	IRSTEM	Input
TAPE6	-	-	-	-	IRSTEM	Output
TAPE8	-	-	-	-	SKYCLOD	Cloud radiance data.



Table 24 (Continued)

Parameter		Units	Defined	Common Block	Primary Routines	Description
Code	Report					
TAPE11	-	V	IRSTEM	-	IRSTEM	Voltage response to background.
TAPE12	-	V	IRSTEM	-	-	Final image file wrt detector description.
TAUA	$\tau_A$	-	LOWEM	LOW	GLINT IRSTEM SKYCLD	(100) Atmospheric transmissivity.
TAUG	$\tau_0$	-	Input 12	GLT	GLINT IRSTEM SKYCLD	(100,3) Optical train transmissivity.
TB	T	°K	Input 4	IMPT	IRSTEM	(40) Background temperature.
TE	$T_E$	°K	Traj	MISS	TGTSIG	Tailpipe temperature.
TF	$T_f$	sec	Sensor	ITRAJ	IRSTEM TRAJR	Frame time.
TGTAU	$\tau_p$	-	Input 10	IMPT	TGTSIG	(100,3) Plume spectral transmission.
TH	$\theta$	rad	GETANG	ANG	FIND SKYCLD	Angle of observer wrt cloud normal.
THL	$\theta_L$	rad	SKYCLD	GLT	GETANG	Zenith angle of observer (IRST) as seen from cloud.
THN	$\theta_N$	rad	Input 21	ANG	GETANG SKYCLD.	Zenith angle of cloud normal.
THO	$\theta_0$	rad	GETANG	ANG	FIND SKYCLD	Angle of sun wrt cloud normal.
THTATS	$\theta_s$	degrees	Traj	ITRAJ	TRAJR	Elevation angle of target wrt zenith (converted to radians internally).

Table 24 (continued)

Parameter Code	Report	Units	Defined	Common Block	Primary Routines	Description
VARRAY	-	-	IRSTEM	GLT	IRSTEM	(64, 64, 6) Real array equivalent to real voltage and complex transform arrays, also used for temporary storage during background calculations.
VCODE	-	V	IRSTEM	-	IRSTEM	(40, 3) Voltage response for each unique background.
VE	-	V	IRSTEM	-	IRSTEM	(3) Path emission voltage response
VEFF	$V_{ideal}$	V	IRSTEM	GLT	GLT/IRSTEM	(64, 64, 3) - Complex - Voltage array before and after glints and clouds
VGLNT	$V_g$	V	GLINT	-	GLINT	(40, 3) Voltage response due to glint.
VNOISE	$v_n$	V	Sensor	-	IRSTEM	RMS noise level.
VT	$V_{ideal}$	V	IRSTEM	-	IRSTEM	(3) Target voltage.
VV	-	-	IRSTEM	INTP	INTER	Interpolation increment size.
V12	-	V	IRSTEM	-	IRSTEM	(40, 3) Response to background diffuse scatter and path radiance.
WAVEL	-	-	IRSTEM	CONST	INTER	(100, 3) Wavelength integration points.
X	$f_p$	-	Data Block	-	INTERP TGTSIG	Plume strength curve wrt aspect angle. Equivalent to FUNC.
XL	$\lambda$	$\mu m$	IRSTEM/BLKBDY TGTSIG	-	BLKBDY	Wavelength.

Table 24 (continued)

Parameter Code	Parameter Report	Units	Defined	Common Block	Primary Routines	Description
XLAML	$\lambda_L$	$\mu\text{m}$	Sensor	GLT	IRSTEM/SKYCLD	(3) Lower bound of passband.
XLAMU	$\lambda_U$	$\mu\text{m}$	Sensor	GLT	FASTEM/SKYCLD	(3) Upper bound of passband.
XX	-	$\mu\text{m}$	Input 8, 10, 12, 14 or 16	CLDS	INTER	(200) Wavelength defining the spectral curve.
YY	-	-	Input 8, 10, 12, 14 or 16	CLDS	INTER	(200) Functional at given wave- length.
YNEW	-	-	INTER	INTP	INTER	(100,3) Interpolated values of function.



#### 4.3 Sample Program

In this section, a sample program is presented including the computer-generated list of the input and output stream. The selected test case is designed to illustrate the use of the parameters contained in the input/output tables (Tables 21 and 23) and is not designed to test all of the code's features.

Table 25 shows the input stream associated with this sample program. The target is flying radially inbound toward a single-color sensor. The background is characterized by three unique elements: a thick cloud, a  $295^{\circ}\text{K}$  graybody at 50 km, and a  $300^{\circ}\text{K}$  graybody at 20 km. It should be noted that the allocation of these background elements to the 4096 element array is not shown on this input list since it is read from a separate source (Tape 1). It also should be noted that the standard plume transmission tabulated input (see Figure 15) of 172 points is not shown here. Instead, a few of the beginning and end points are shown along with the  $\tau_A$  values which bound the 3.8 - 4.2 $\mu\text{m}$  passband selected for this test case. Similarly, only the first few lines of the solar irradiance spectrum (Figure 3) are shown in the interest of brevity. Also not shown are a large number of inputs required by the propagation model. These inputs are the standard LOWTRAN inputs covered in reference 4. The last few lines of the input stream define the cloud angles, position, and the two glint points.

In Table 26 the corresponding outputs for this test case are shown as they appear for the NBUG=0 with two exceptions. First, the time loop is truncated after three iterations ( $t=0, 1$  and 2 seconds) even though TMAX=10 seconds. Second, several array print-outs are included which normally are printed only if NBUG>0. These additional array plots are (1) the background inputs after index normalization, (2 and 3) the signal response after the target has been added, for the minimum and maximum array normalization but before the glint and system noise are included and (4) one of the transformed arrays. Many more arrays are printed if NBUG>0 but are not shown here. Of course, these arrays contain more informa-

tion than is required since only those rows corresponding to detector centers are stored on Tape 12 and subsequently used in the signal processing analyses. With respect to the standard time-loop printouts, it should be noted that the target's projected area and its spectral intensity are repeated even though they do not change for this radially-inbound trajectory. These printouts have been included in anticipation of time-varying signatures and trajectories to be incorporated in later versions of IRSTEM.

Table 25  
Sample Input Stream

```

64 64 1
5 260. .75 .9 20000.
8 295. .6 .001 50000.
7 300. .75 .1 20000.

$SENSOR XLAM(2)=0.,XLAM(3)=0.,XLAM(3)=0.,TF=1.,D=.1,
DX=4.E-05,DY=4.E-04,OVL=4.E-05,FL=.15,F0=1.E+04,ELUS=80.,VNOISE=1.E-04,
DPRK=1.E+08,DSTRPK=1.E+11$

```

[illegible]

2.000	3.72E+02	2.190	3.72E+02	2.381	3.72E+02	2.571	5.00E+02
2.762	8.41E+02	2.952	3.90E+03	3.143	7.34E+02	3.333	4.90E+02
3.524	4.97E+02	3.714	4.98E+02	3.905	4.71E+02	4.095	4.82E+02
4.286	1.59E+04	4.476	1.69E+04	4.667	1.60E+04	4.857	5.77E+03
5.048	2.12E+03	5.238	4.38E+02	5.429	1.04E+03	5.619	1.39E+03
5.810	3.17E+03	6.000	2.34E+03	6.190	2.98E+02	6.381	6.69E+03
6.571	7.65E+03	6.762	7.15E+03	6.952	6.65E+03	7.143	6.15E+03
7.333	4.41E+02	7.524	7.25E+02	7.714	7.91E+02	7.905	6.61E+02
8.095	7.80E+02	8.286	6.45E+02	8.476	5.85E+02	8.667	3.97E+02
8.857	2.78E+02	9.048	2.93E+02	9.238	2.84E+02	9.429	2.51E+02
9.619	2.19E+02	9.809	1.87E+02	10.000	1.54E+02	10.190	1.64E+02
10.381	1.73E+02	10.571	1.82E+02	10.762	1.91E+02	10.952	2.00E+02
11.143	2.10E+02	11.333	2.19E+02	11.524	2.29E+02	11.714	2.39E+02
11.905	2.48E+02	12.095	2.65E+02	12.286	2.68E+02	12.476	3.11E+02
12.667	3.35E+02	12.857	3.58E+02	13.048	3.73E+02	13.238	3.61E+02
13.429	3.49E+02	13.619	3.38E+02	13.809	3.25E+02	14.000	3.14E+02

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Table 25 (continued)

Input 9  
Input 10

1.9993	0.8147
2.0093	0.8100
2.0193	0.8057
2.0297	0.8017
2.0401	0.8000
3.7710	0.9042
3.8067	0.9042
3.8435	0.9091
3.8808	0.9100
3.9188	0.9101
3.9575	0.9196
3.9971	0.9283
4.0375	0.9344
4.0787	0.9399
4.1207	0.9460
4.1636	0.9498
4.2074	0.9545
4.2521	0.9597
4.2978	0.9667
4.3445	0.9603
12.0150	0.2210
12.4720	0.1677
12.8730	0.1592
13.3020	0.1383
13.7590	0.1221

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Table 25 (continued)

Input 11	Input 12	Input 13	Input 14	Input 15	Input 16
3.1	.1	3.2	.5	3.3	.8
4.6	.5	4.7	.1		
5					
2.	5. E+103.	7. E+104.	9. E+104.6	1. E+11	
5.	9. E+10				
187					
1.000E+00	2.726E-02	1.100E+00	5.077E-02	1.200E+00	3.541E-02
1.400E+00	5.832E-03	1.500E+00	1.794E-02	1.600E+00	2.202E-02
1.800E+00	6.991E-03	1.900E+00	1.682E-05	2.000E+00	1.633E-03
2.200E+00	7.259E-03	2.300E+00	5.464E-03	2.400E+00	3.266E-03
2.600E+00	0.	2.700E+00	0.	2.800E+00	0.
3.000E+00	8.412E-05	3.100E+00	1.580E-04	3.200E+00	9.946E-05
3.400E+00	3.479E-04	3.500E+00	5.707E-04	3.600E+00	7.103E-04
3.800E+00	7.903E-04	3.900E+00	7.394E-04	4.000E+00	6.524E-04
4.200E+00	0.	4.300E+00	0.	4.400E+00	0.
4.600E+00	1.705E-04	4.700E+00	2.316E-04	4.800E+00	1.900E-04
5.000E+00	4.603E-05	5.100E+00	2.797E-05	5.200E+00	5.853E-06
5.400E+00	0.	5.500E+00	0.	5.600E+00	0.
5.800E+00	0.	5.900E+00	0.	6.000E+00	0.
6.200E+00	0.	6.300E+00	0.	6.400E+00	0.
6.600E+00	0.	6.700E+00	0.	6.800E+00	0.
7.000E+00	0.	7.100E+00	0.	7.200E+00	0.
7.400E+00	2.163E-07	7.500E+00	6.301E-07	7.600E+00	1.788E-06
7.800E+00	3.887E-06	7.900E+00	6.026E-06	8.000E+00	1.263E-05
8.200E+00	2.150E-05	8.300E+00	2.486E-05	8.400E+00	2.631E-05
8.600E+00	2.709E-05	8.700E+00	2.639E-05	8.800E+00	2.549E-05
9.000E+00	2.157E-05	9.100E+00	2.144E-05	9.200E+00	1.993E-05
9.400E+00	7.732E-06	9.500E+00	9.759E-06	9.600E+00	6.719E-06
9.800E+00	8.034E-06	9.900E+00	9.924E-06	1.000E+01	1.166E-05
1.020E+01	1.282E-05	1.030E+01	1.274E-05	1.040E+01	1.244E-05
1.060E+01	1.190E-05	1.070E+01	1.147E-05	1.080E+01	1.079E-05
1.100E+01	9.728E-06	1.110E+01	9.354E-06	1.120E+01	7.107E-06
1.140E+01	6.600E-06	1.150E+01	6.956E-06	1.160E+01	7.301E-06
1.180E+01	7.630E-06	1.190E+01	5.281E-06	1.200E+01	5.519E-06
1.220E+01	3.684E-06	1.230E+01	3.126E-06	1.240E+01	2.601E-06
1.260E+01	1.230E-06	1.270E+01	1.230E-06	1.280E+01	2.043E-06

```

*****  KAS=20000., IV=200., DT=0.01, B, HINIS=29.943, PHIS=99.164, IIR=1.32,
*****  WFL=0., WF=25., IE=2500., IR=40., IS=34., EIR=8., EIS=3., EIE=8.,
*****  ASPECT=10., INAX=10.8
*****  SSUM KLAT=45., KLONG=0., MON=1., DAY=28., HR=14., PHL=180.8
*****
5 34
2.830E+03 1.245E+03 5.374E+02 2.257E+02 1.193E+02 8.992E+01 6.341E+01 5.893E+01
5.673E+01 5.822E+01 5.679E+01 5.320E+01 5.569E+01 5.159E+01 5.052E+01 4.747E+01
4.451E+01 4.466E+01 4.317E+01 3.636E+01 2.659E+01 1.935E+01 1.453E+01 1.114E+01
8.831E+00 7.434E+00 2.239E+00 5.893E-01 1.551E-01 4.084E-02 1.078E-02 5.553E-05
1.970E-08-0.
1.379E+04 5.034E+03 1.845E+03 6.735E+02 2.454E+02
0.0 1.013E+03 300.0 1.9E-01 5.6E-05 1.013E+03 294.0 1.4E-01 6.0E-05
1.0 9.040E+02 294.0 1.3E+01 5.5E-05 9.020E+02 290.0 9.3E+00 6.0E-05
2.0 8.050E+02 288.0 9.3E+00 5.4E-05 8.020E+02 285.0 5.9E+00 6.0E-05
3.0 7.150E+02 284.0 4.7E+00 5.1E-05 7.100E+02 279.0 3.3E+00 6.2E-05
4.0 6.330E+02 277.0 2.2E+00 4.7E-05 6.280E+02 273.0 1.9E+00 6.4E-05
5.0 5.590E+02 270.0 1.5E+00 4.5E-05 5.540E+02 267.0 1.0E+00 6.6E-05
6.0 4.920E+02 264.0 8.5E-01 4.3E-05 4.870E+02 261.0 6.1E-01 6.9E-05
7.0 4.320E+02 257.0 4.7E-01 4.1E-05 4.260E+02 255.0 3.7E-01 7.5E-05
8.0 3.760E+02 250.0 2.5E-01 3.9E-05 3.720E+02 248.0 2.1E-01 7.9E-05

```

Input 19
Input 20
Input 21
Input 22
Input 31
Input 32
Input 33



Table 26  
Sample Output

GROUP SIZE I= 64 J= 64

DUMMY BACKGROUND TAPE

KEY	T(DEG K)	EMISS	RHD	RANGE(M)
6	.124	.750	.900	20000.000
8	.124	.600	.001	50000.000
7	.124	.750	.100	20000.000

TRAJ MODE NO BANDS LOW BOUND(MICRONS) UPPER BND(MICRONS) TARGET NAME

1	1	3.800	4.200	DUMNYTGT
		0.000	0.000	

MODEL AIR HAZE OPT PATH TYPE EMISS HSAI ELV SENSOR(M) INCREMENTS(MICRONS)

2	1	2	1	1	15.00	.04000
---	---	---	---	---	-------	--------

SCAN TIME(SEC) OPTICS DIA(M) DETECTOR WIDTH(M) DETECTOR LENGTH(M) DETECTOR OVERLAP(M)

1.000	.100	.4000E-04	.4000E-03	.4000E-04
-------	------	-----------	-----------	-----------

FOCAL LENGTH(M) CUTOFF FREQ.(HZ) BACKGROUND ELV(SEC) RMS NOISE LEVEL(V) PEAK RESPONSIVITY(V/U) PEAK DSTAR(CM/HZ\*\*2/U)

.150	10000.000	80.000	.100000E-02	.100000E+09	.100000E+12
------	-----------	--------	-------------	-------------	-------------

WAVELENGTH (MICRONS)	OPTICAL TRANSMISSION	DETECTIVITY (CM/HZ**2/U)	RESPONSIVITY (V/U)	SOLAR IRRAD (U/CM**2)
.377E+01	.800E+00	.853E+11	.853E+08	.797E-03
.380E+01	.800E+00	.860E+11	.860E+08	.789E-03
.384E+01	.800E+00	.868E+11	.868E+08	.771E-03
.388E+01	.800E+00	.875E+11	.875E+08	.752E-03
.391E+01	.800E+00	.883E+11	.883E+08	.727E-03
.395E+01	.800E+00	.891E+11	.891E+08	.694E-03
.397E+01	.800E+00	.898E+11	.898E+08	.659E-03
.403E+01	.800E+00	.905E+11	.905E+08	.571E-03
.407E+01	.800E+00	.912E+11	.912E+08	.468E-03
.412E+01	.800E+00	.919E+11	.919E+08	.340E-03
.416E+01	.800E+00	.926E+11	.926E+08	.168E-03
.420E+01	.800E+00	.934E+11	.934E+08	0.

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Table 26 (continued)

```

***** TARGET INFORMATION *****
INIT. RANGE(M)  VELOCITY(M/SEC)  DIAMETER(M)  LENGTH(M)  THETA POSITION(DEG)  PHI POSITION(DEG)
30000.000      00.000      .660      5.280      79.908      90.189

NOSE LENGTH(M)  TAILPIPE DIA(M)  TAILPIPE TEMP(K)  NOSE TEMP(K)  SKIN TEMP(K)
1.320          28.000          2500.000          409.000          348.000

NOSE EMISSIVITY  SKIN EMISSIVITY  TAILPIPE EMISSIVITY
.800            .800            .800

VELO ANGLE(DEG)  MAX. ENCOUNTER TIME(SEC)
10.000          10.000

***** SUN INFORMATION *****
LATITUDE(DEG)  LONGITUDE(DEG)
45.000          0.000

MONTH  DAY  HOUR
1      28.  14.

TRUE BEARING L.O.S(DEG)
180.000

TARGET SIGNATURE(WATTS/STR/MICRON)
MICRONS  NOSE  BODY  TAILPIPE  TOTAL
3.766    4.521  1.290  0.000    121.630    127.449
3.802    4.709  1.364  0.000    121.316    127.389
3.839    4.902  1.442  0.000    120.988    127.333
3.876    5.101  1.524  0.000    120.654    127.279
3.914    5.305  1.610  0.000    120.290    127.205
3.951    5.515  1.699  0.000    119.841    127.055
3.992    5.730  1.793  0.000    119.393    126.906
4.032    5.951  1.891  0.000    118.915    126.757
4.073    6.177  1.994  0.000    118.430    126.609
4.115    6.409  2.100  0.000    518.530    527.038
4.158    6.645  2.212  0.000    1365.238    1374.095
4.202    6.887  2.328  0.000    2229.734    2238.949

AREAS(M**2)
NOSE  BODY  TAILPIPE  TOTAL
.41   .61   0.00   1.02

AT TIME"  0.00000  TARGET SIZE IS  .1018E+01  50 M
TOT RANGE(M)  .3000E+05  TOT VOLUME  .568E+01  0.

```

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Table 26 (continued)

TARGET SIGNATURE (WATTS/STR/MICRON)	NOSE	BODY	TAILPIPE	PLUME	TOTAL
3.766	4.521	1.290	0.000	121.638	127.449
3.802	4.709	1.364	0.000	121.316	127.389
3.839	4.902	1.442	0.000	120.988	127.333
3.876	5.101	1.524	0.000	120.654	127.279
3.914	5.305	1.610	0.000	120.290	127.205
3.953	5.515	1.699	0.000	119.841	127.055
3.992	5.730	1.793	0.000	119.383	126.906
4.032	5.951	1.891	0.000	118.915	126.757
4.073	6.177	1.994	0.000	118.438	126.609
4.115	6.409	2.100	0.000	518.530	527.038
4.158	6.645	2.212	0.000	1365.238	1374.095
4.202	6.887	2.328	0.000	2239.734	2238.949

AREAS(M\*\*2)

NOSE .41 BODY .61 TAILPIPE 0.00 TOTAL 1.02  
AT TIME 1.00000 TARGET SIZE IS .1018E+01 SD M  
TGT RANGE(M) .2940E+05 TGT VOLTAGE .5931E-01 0.  
TARGET SIGNATURE(WATTS/STR/MICRON)

TARGET SIGNATURE (WATTS/STR/MICRON)	NOSE	BODY	TAILPIPE	PLUME	TOTAL
3.766	4.521	1.290	0.000	121.638	127.449
3.802	4.709	1.364	0.000	121.316	127.389
3.839	4.902	1.442	0.000	120.988	127.333
3.876	5.101	1.524	0.000	120.654	127.279
3.914	5.305	1.610	0.000	120.290	127.205
3.953	5.515	1.699	0.000	119.841	127.055
3.992	5.730	1.793	0.000	119.383	126.906
4.032	5.951	1.891	0.000	118.915	126.757
4.073	6.177	1.994	0.000	118.438	126.609
4.115	6.409	2.100	0.000	518.530	527.038
4.158	6.645	2.212	0.000	1365.238	1374.095
4.202	6.887	2.328	0.000	2239.734	2238.949

AREAS(M\*\*2)

NOSE .41 BODY .61 TAILPIPE 0.00 TOTAL 1.02  
AT TIME 2.00000 TARGET SIZE IS .1018E+01 SD M  
TGT RANGE(M) .2660E+05 TGT VOLTAGE .6176E-01 0.



Table 26 (continued)

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[illegible]

Table 26 (continued)

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BACK GROUND VOLTAGES AND TARGET SCALE FACTOR= .10E+05 INTERVAL NO. 1

[illegible]



Table 26 (continued)

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BACK GROUND VOLTAGES AND TARGET SCALE FACTOR= .10E+03 INTERVAL NO. 1

[illegible]



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[illegible]

## Section 5

### CONCLUSIONS

The initial development of the Infrared Search and Track System Evaluation Model is now complete; however, the refinements and modifications required to make the code more flexible and enable it to reach its full potential is far from complete. IRSTEM contains a number of unique features, which are expected to make it a valuable tool for analyzing electro-optical sensors. These features include the detailed, deterministic background description which obviates the need for simplifying assumptions about the background statistics. The cloud reflection and radiation computations, the inclusion of sun glints and the ability to input detailed sensor characteristics are also expected to be useful analysis features. In addition, the separation of spectrally- and spatially-dependent effects, is expected to facilitate future IRSTEM modifications. The overall goal of this code is to produce an accurate time-history of the voltage response from each detector so that analysts can evaluate different signal processing techniques. Such analyses should predict the operational performance of surveillance sensors better than can now be done with the statistical background threshold-crossing processing analysis.

The code described in this report is now operating but has undergone only limited testing to date. It is expected that a series of modifications and corrections will be required to fully debug the program and bring it to its full potential. In addition, there are a number of limitations associated with the present version of IRSTEM which should be corrected as time allows. One of the major limitations is the small field-of-view which is necessitated by the tradeoff between the required sensor resolution and computer core limitations. It is felt that the basic 64 by 64 array of 0.2 mr pixels can provide statistically meaningful results without overloading the computer. If one wishes to increase the field-of-view, this can be done by inputting a larger array (IMAX, JMAX), incorporating larger pixels or imposing a moving background. The moving background approach could follow the target and access information from a data tape or simply, fold the background back upon itself as the target moves. The moving background would allow the user to have an effective larger background without

increasing the core size or sacrificing sensor resolution.

Even with the size background now modelled in IRSTEM, the code may be too large for some users. Work is underway to reduce the code size by shortening the LOWEM subroutine and reducing the sun glint calculations. Another option is to split the code into two or more pieces. Referring back to Figure 23, one can see that there is a natural break point between the one-time-only calculations and the major time loop. In addition, if the target signature and glint calculations are moved to the one-time only calculations, the calls to LOWEM can be eliminated in the time-loop, and portions of the program can be overlaid to reduce the core size requirements.

Another limitation is the fact that the code models only radially inbound missiles. The graybody signature calculation used for these targets is a simplistic one, and the computations terminate when the target exceeds the pixel size. Finally, jitter and turbulence have not been incorporated into the code as of this time.

Work is underway to expand the capabilities of IRSTEM and eliminate many of the limitations identified above. However, even when these modifications are completed, there is still a large number of options available for increasing the flexibility and utility of IRSTEM. For example, one may wish to incorporate generalized trajectory and signature computations which are time-varying and allow the user to model target maneuvers and missile burnout. Another growth option is to predict false alarm rates. The present code is designed to analyze the probability of target detection against a variety of backgrounds but it is not optimum for analyzing false alarms because of its deterministic approach. There are techniques, however, which can be used to obtain statistical information on the false alarms using the random noise portion of the program. Finally, even though the present code is structured to model the wide field-of-view surveillance systems, the basic methodology is also applicable to FLIRS, reticle seekers and non-scanning sensors.



At present, it appears that IRSTEM testing should continue using existing hardware and field test data whenever available. In addition, it is now ready to predict the performance of advanced concepts. Performing such analyses will not only uncover subtle coding errors but also will lead to logic modifications which will improve the accuracy and utility of IRSTEM.

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Appendix A  
IRSTEM Listings



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PROGRAM JKST(INPUT, OUTPUT, TAPES, TAPES-OUTPUT, TAPE1, TAPE3-TAPES, TAP
1E11, TAPE12, TAPE8)
PROGRAM JKST1 READS IN A BACKGROUND SCENE AND CONVERTS THE BACKGR
OUND TO A SIMULATED VOLTAGE. A TARGET IS SUPERIMPOSED UPON THE
SCENE, AND ITS VOLTAGE CONTRIBUTION CALCULATED. THE VOLTAGE
ARRAY IS TRANSFORMED FOR EASE OF INCLUDING OPTICAL TRANSFER FCTS.
AND ELECTRONIC EFFECTS. THE MODIFIED ARRAY IS REFORMED
AND NOISE IS ADDED. IF THE ENCOUNTER TIME HAS NOT BEEN EXCEEDED
A NEW POSITION OF THE TARGET IS CALCULATED AND ITS PREVIOUS CALCUL
ATIONS ARE REPEATED.
INPUT DATA
*****
TAPE 1 CONTAINS THE BACKGROUND
CARDS TO DEFINE BACKGROUND CODES.
KEY (1), TB(1), EB(1), KNO(1), KNO(1), KNO(1)
15, 4 F 10.3
SENSOR NAMELIST -
XLAN(1), XLAN(2), XLAN(3), XLAN(1), XLAN(2), XLAN(3), IF, D,
DX, DY, DLV, FL, FD, ELVS, KNOISE, KNOISE, KNOISE
LOUSE DATA
MODEL, THAZE, ITYPE, IEMIS, HS, DV(1), DV(2), DV(3), DSAL
4F5, 4F10.3, 15
PLUME SIGNATURE IJP
N - NUMBER OF POINTS
(LAMBDA(1), IJP(1), I=1,N)
TRANSMISSION THRU THIS PLUME
IGTAD
N
(LAMBDA(1), IGTAD(1), I=1,N)
OPTICAL TRANSMISSION
N
(LAMBDA(1), IGTAD(1), I=1,N)
DETECTOR RESPONSE
N
(LAMBDA(1), KD(1), I=1,N)
SOLAR SCATTER
N
(LAMBDA(1), SK(1), I=1,N)
TRAJECTORY NAMELIST
AS, IV, VI, VI, INT ATS, PHITS, INF TOL, LP, TE, FO, IS, EIM, ETS,
EIE, ASPECT, IMAX

```

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```

C  ARRAY SIZE IS READ FIRST
C  IMAX, JMAX, NBUG
C  315
C  SUB RARELIST
C  KLAT, KLONG, MON, DAY, HR, PHL.
C  DIMENSION HUL(5)
C  DIMENSION VARRY(64,64,6)
C  DIMENSION IBRG(64,64)
C  DIMENSION VI(3), VE(3)
C  DIMENSION IVEFF(64,64,3), H(64,64,3), V(64,64,6)
C  DIMENSION EFF(64,64,3)
C  EQUIVALE=
C
C  EQUIVALENCE (VARRY(1,1,1),VEFF(1,1,1))
C  EQUIVALENCE (IVEFF(1,1,1),VEFF(1,1,1)), (H(1,1,1),VEFF(1,1,1))
C  EQUIVALENCE (L,LL), (EFF(1,1,1),VEFF(1,1,1)), (V(1,1,1),VARRY(1,1,1))
C
C  COMPLEX VEFF, IVEFF, EFF, H
C  DIMENSION YNEW(100,3)
C  EQUIVALENCE (YNEW(1),YNEW(1,1))
C  DIMENSION V12(20,3), VCODE(20,3)
C  COMMON /INTG/ NPU(3),LL,BU(3),BL(3),DU,CV(3),NBANDS
C  COMMON /INTP/ DUM(300),IFLAG,LM,VU
C  COMMON /LOU/ TAU(100),APR(100)
C  DIMENSION TOTRAN(2000)
C  REAL INTERP
C  DIMENSION RH(299)
C  LOGICAL FIRST
C  COMMON /IKAJ/ KS,IV,DI,TL,ELVS,INTATS,PHITS,IF,MODEI,II,JJ,R,ASPE
C  ICT,1,AT,TEKOK,TJ(100,3)
C  COMMON /CLUS/ XX(200),YY(200)
C  DIMENSION BV(3)
C  COMMON /KST/ TOTRAN,I20,I22,I23,I24,I25,I26,I27,I28,I29,I210,I211
C  I,I212,K21,K22,K23,K24
C  COMMON /GLI/ KLAT,KLONG,MON,DAY,HR,INL,PHL,IC1,IC2,IC3,IC4,IC5,IC6
C  I,KU(100,3),TAUD(100,3),XLAND(3),XLAND(3),VEFF(64,64,3),INIT
C  DIMENSION LVEL(16)
C  COMMON /FRT/ IBRG,JMAX,IMAX,NBUG
C  COMMON /POST/ ANGLE(12),FUNC(12)
C  COMMON /INT/ TB(10),EB(10),KHO(10),KEY(10),TJF(100,3),SK(1
C  100,3),IGTAU(100,3)
C  COMMON /MISS/ INL,IFL,DP,IE,IN,IS,ETN,EIS,EIE
C  COMMON /CONST/ MODEL,INAZE,ITYPE,ITEMS,HS,MSAI,NAVEL(100,3)
C  COMMON /MISC/ D,FI,C1,C2,DEGRAD,M1,H2
C  DATA LVEL/BNACK GKO,BHUND VOLT,BHAGES AND,BH TARGET ,BHTRANSFOR,
C  BHNED VALU,BHUES INVE,BHKESE ,BHTRANSFOR,BHNED VALU,BHE KEAL ,
C  BHN INAG ,BHDTECTOR,BH ARRAY V,BHVALUES ,BH /
C  BHNELIST /SENSOR/ XLAND,XLAND,IF,D,DX,DY,DVL,FL,F0,ELVS,WDIUSE,KDP
C  IE,DSIRPK
C  BHNELIST /IKAJ/ KS,IV,DI,TL,INTATS,PHITS,INL,IFL,DP,IE,IN,IS,ETN,E
C  IIS,EIE,ASPECT,IMAX

```

[illegible]



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      DATA FIRST/.INDEX./
      CL=2.997925E8
      HP=6.62554E-34
      HOK=1.79924E-11
      WEGGAB=3.14159365/180.
      IERROR=0
      IZERO=0
      C1=3.713E+04
      C2=1.4388E+04
      KMIN=9999999999999999.
      IFLAG=0
      PI=3.14159265
      READ BKG TAPE
      READ (1,61) HOL,MXCODE
      WRITE (6,59) HOL
      READ (1,60) (IIRG(I),I=1,IMAX),J=1,JMAX)
      READ BACKGROUND CODE AND CORRESPONDING VALUES.
      WRITE (6,57)
      DO 1 I=1,MXCODE
      READ (5,52) KEY(I),T6(I),E6(I),KHO(I),KB(I)
      1 WRITE (6,58) KEY(I),T6(I),E6(I),KHO(I),KB(I)
      IF (IIRG(I).GT.0) WRITE (6,56) (J,J=1,JMAX),I,I=1,IMAX)
      1=1,IMAX)
      C MODIFY BACKGROUND ARRAY SO CODES BECOME INDICES.
      DO 4 I=1,IMAX
      DO 4 J=1,JMAX
      DO 2 K=1,MXCODE
      IF (IIRG(I),J).EQ.KEY(K) GO TO 3
      2 CONTINUE
      3 IIRG(I,J)=K
      IF (KEY(K).EQ.1) IC1=K
      IF (KEY(K).EQ.2) IC2=K
      IF (KEY(K).EQ.3) IC3=K
      IF (KEY(K).EQ.4) IC4=K
      IF (KEY(K).EQ.5) IC5=K
      IF (KEY(K).EQ.6) IC6=K
      4 CONTINUE
      C FIND MAX AND MIN RANGE.
      C REPLACE DUPLICATE RANGES WITH AN APPROPRIATE INDEX.
      MX=MXCODE-1
      DO 6 K=1,MX
      L=K+1
      IF ((KEY(K)-5).LE.0) GO TO 6
      DO 5 M=L,MXCODE
      IF (KB(M).LT.100) GO TO 6
      IF (KB(K).LT.KMIN) KMIN=KB(K)
      IF (KB(K).GT.KMAX) KMAX=KB(K)
      IF (KB(M).EQ.KB(K)) KB(M)=K
      5 CONTINUE
      6 CONTINUE
      C READ SENSOR INFO., LOREM INFO., AND HAVE BANDS OF INTEREST
      A 142
      A 143
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      A 192

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      READ (5,5) SENSUR
      READ (5,5) MODEL,MBANDS,XLAM(1),XLAMU(1),NAMEI
      READ (5,5) MODEL,INIZE,ITYPE,IEMIS,MS,DV,NSAI
      WRITE (6,42) MODEL,MBANDS,XLAM(1),XLAMU(1),NAMEI,(XLAM(1),XLAMU(
1)),J-2,MBANDS
      WRITE (6,43) MODEL,INIZE,ITYPE,IEMIS,NSAI,MS,(DV(1),I-1,MBANDS)
      WRITE (6,44) IF,D,DV,DVL,FL,FD,ELVS,VNOISE,HOPK,DSINKP
      NI=MS+.001
      C  CHANGE WAVELENGTH TO INVERSE CM.
      DO 7 I=1,MBANDS
        CV(L)=INT(10000.+(DV(L)/(XLAM(L)+XLAM(1)))
        BL(L)=INT((10000./XLAMU(L))/5.)+5
        BU(L)=INT((10000./XLAM(L))/5.)+1+5
        CV(L)=INT(CV(L)/5.)+5.
        IF (CV(L).LT.5) CV(L)=5
        NPU(L)=(CV(L)-BL(L))/CV(L)
        IF (CV(L)+NPU(L)+BL(L).LT.BU(L)) NPU(L)=NPU(L)+1
        NPU(L)=NPU(L)+1
        LN=NPU(L)
      DO 7 I=1,LN
        N=LN-(I-1)
        WAVE(L,N)=10000./(CV(L)+(I-1)+BL(L))
      / CONTINUE
      C  READ TARGET SIG
      CALL INTER
      C  READ IN CURVES AND CHANGE UNITS OF WAVELENGTH TO INVERSE CM.
      DO 8 I=1,MBANDS
        LN=NPU(L)
      DO 8 I=1,LN
        B IJP(I,L)=YNEW(I,L)
      CALL INTER
      DO 9 I=1,MBANDS
        LN=NPU(L)
      DO 9 I=1,LN
        9 TGTAD(I,L)=YNEW(I,L)
      C  READ TRANSMISSIVITY OF OPTICS
      CALL INTER
      DO 10 I=1,MBANDS
        LN=NPU(L)
      DO 10 I=1,LN
        10 TADUC(I,L)=YNEW(I,L)
      C  CALC DETECTOR RESPONSE
      CALL INTER
      DO 11 I=1,MBANDS
        LN=NPU(L)
      DO 11 I=1,LN
        11 R(I,L)=YNEW(I,L)
      IF R(I,L)-YNEW(I,L).GE.DENK/DSINKP
      C  SET FLAG FOR SOURCE DATA
      CALL INTER
      DO 12 I=1,MBANDS

```

```

1  IN=HVAL
DO 12 I=1,IN
12 SK(I,1)=YHEW(I,1)
WRITE (6,46)
DO 13 L=1,NBANDS
WRITE (6,45)
LN=NPUL(1)
WRITE (6,47) (HVAL(I,1),TAUD(I,1),TJ(I,1),KD(I,1),SK(I,1),I=1,IN)
13 CONTINUE
C READ TRAJECTORY INFO.
READ (5,IRAJ)
WRITE (6,48) KS,IV,VI,IL,INTATS,PHITS,IML,UP,IE,IR,IS,EIN,EIS,EIE,
IASPECT,IMAX
READ (5,SUM)
WRITE (6,49) KLAT,ALONG,MON,DAY,HR,PHL
ELVS=ELVS+DEGRAD
PKD=IMAX+JMAX
IF (NBUG.GT.0) WRITE (6,55) (J,J=1,JMAX),(I,(IBKG(I,J),J=1,JMAX),I
I=1,IMAX)
C ONE TIME ONLY CALCULATIONS.
INTATS=INTATS+DEGRAD
THETAS=THETAS+DEGRAD
PHITS=PHITS+DEGRAD
I=1-IF
12=IMAX/2
J2=JMAX/2
JO=J2+1; IO=I2+1
IF (IMAX-(I2*2).GT.0) JO=J2
IF (JMAX-J2*2.GT.0) JO=J2
YC=2.E-04*FL
VS=2.*PI*FL/TF
Y=2.E-04*IMAX*FL
X=2.E-04*JMAX*FL
DELTAIX=2.*PI/X
DELTAY=2.*PI/Y
ADET=DX*DY
IML=(Y-DY)/(DY-OVL)+1.
J=0
C THIS BEGINS MAIN LOOP FOR FORMING
C VOLTAGES TO REPRESENT BACKGROUND.
DO 22 K=1,NXCODE
IF (K.EQ.1ET.DR.K.EQ.IC2.DR.K.EQ.IC3.DR.K.EQ.IC4.DR.K.EQ.IC5) GO 1
10 22
IF (K.EQ.IC6) GO 10 22
H2=H1*KB(K)+CDS(ELVS)*.001
FORM FCTS. AND INTEGRATE FOR EACH WAVEBAND.
DO 21 L=1,NBANDS
LN=NPUL(L)
IF (K*KB(K).GT.100) GO 10 15
V12(K,L)=V12(IFIX(K*KB(K)),L)
J1=(IFIX(K*KB(K))-1)*100

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C
DO 14 J=1,LM
14 TAU(J)=VARRY(J,J)
GO TO 19
C
C BOUNDS FOR LOUEN
15 U1=XLAN(L)
U2=XLAN(L)
VV=VV(L)
S=KB(K)*.001
LM=HFM(L)
CALL LOUEN (MODEL,IMAZE,ITYPE,I21,I22,I23,I24,I25,I26,I27,I28,I29,I30,I31,I32,I33,I34,I35,I36,I37,I38,I39,I40,I41,I42,I43,I44,I45,I46,I47,I48,I49,I50,I51,I52,I53,I54,I55,I56,I57,I58,I59,I60,I61,I62,I63,I64,I65,I66,I67,I68,I69,I70,I71,I72,I73,I74,I75,I76,I77,I78,I79,I80,I81,I82,I83,I84,I85,I86,I87,I88,I89,I90,I91,I92,I93,I94,I95,I96,I97,I98,I99,I100,I101,I102,I103,I104,I105,I106,I107,I108,I109,I110,I111,I112,I113,I114,I115,I116,I117,I118,I119,I120,I121,I122,I123,I124,I125,I126,I127,I128,I129,I130,I131,I132,I133,I134,I135,I136,I137,I138,I139,I140,I141,I142,I143,I144,I145,I146,I147,I148,I149,I150,I151,I152,I153,I154,I155,I156,I157,I158,I159,I160,I161,I162,I163,I164,I165,I166,I167,I168,I169,I170,I171,I172,I173,I174,I175,I176,I177,I178,I179,I180,I181,I182,I183,I184,I185,I186,I187,I188,I189,I190,I191,I192,I193,I194,I195,I196,I197,I198,I199,I200,I201,I202,I203,I204,I205,I206,I207,I208,I209,I210,I211,I212,I213,I214,I215,I216,I217,I218,I219,I220,I221,I222,I223,I224,I225,I226,I227,I228,I229,I230,I231,I232,I233,I234,I235,I236,I237,I238,I239,I240,I241,I242,I243,I244,I245,I246,I247,I248,I249,I250,I251,I252,I253,I254,I255,I256,I257,I258,I259,I260,I261,I262,I263,I264,I265,I266,I267,I268,I269,I270,I271,I272,I273,I274,I275,I276,I277,I278,I279,I280,I281,I282,I283,I284,I285,I286,I287,I288,I289,I290,I291,I292,I293,I294,I295,I296,I297,I298,I299,I300,I301,I302,I303,I304,I305,I306,I307,I308,I309,I310,I311,I312,I313,I314,I315,I316,I317,I318,I319,I320,I321,I322,I323,I324,I325,I326,I327,I328,I329,I330,I331,I332,I333,I334,I335,I336,I337,I338,I339,I340,I341,I342,I343,I344,I345
20,MSAT)
JJ=(K-1)*100
DO 16 J=1,LM
16 VARRY(JJ+J)=TAUA(J)
DO 17 I=1,LM
17 DUM(I)=APR(I)+TAUD(I,L)*KD(I,L)
CALL INTEG
C
C FIRST INTEGRAL FORMED AND INTEGRATED
DUM(I)=DUM(I)*10.
V12(K,L)=DUM(I)
DO 18 I=1,LM
18 DUM(I)=SK(I,L)+TAUD(I,L)*KD(I,L)
CALL INTEG
C
C SECOND INTEGRAL FORMED AND INTEGRATED
V12(K,L)=V12(K,L)+KDU(K)+DUM(I)*10000./PI
19 DO 20 I=1,LM
XL=NAVEL(I,L)
F=BLKBDY(TB(K),XL,C1,C2)
EMITTANCE CALC
20 DUM(I)=F*TAUA(I)+TAUD(I,L)*KD(I,L)+1.E+04*EB(K)/PI
CALL INTEG
C
C THIRD INTEGRAL FORMED AND INTEGRATED
VCODE(K,L)=(V12(K,L)+DUM(I))*D*PI+.000000001
21 CONTINUE
22 CONTINUE
DO 23 L=1,NBANDS
DO 23 I=1,IMAX
DO 23 J=1,JMAX
23 VEFF(I,J,L)=VCODE(TBKG(I,J),L)
CALL SKYCLD
WRITE (11) VEFF
24 REWIND 11
READ (11) VEFF
CALL GLINT
CALL TRAJ ROUTINE TO FIND THE POSITION OF THE TARGET
IF (ERRKOR.NE.0) STOP
CALL IGTSIG
ASPECK=1.
C
C THIS CONSTANT WILL BE A FUNCTION OF ANGLE

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YRK=YRK+DTA.2
IF (XK0.GT.1.) XK0=.9999
OTF=2.*(ACOS(XK0)-XK0*SQRT(1.-XK0*XK0))/PI
ELE=XK*VS/12.*PI*FD)
HELECT=1./((50K(1).ELC+ELC))
HDET=HDET+SH(XRK)*SH(YRK)/(XRK*YRK)
IF (1+10.GT.IMAX) GO TO 29
IF (19KG(1+10,J0).NE.0) GO TO 29
19KG(1+10,J0)=1
H(1+10,J0,L)=HDET*HELECT*OTF+TVEFF(1+10,J0,L)
29 CONTINUE
IF (J0+J0.GT.JMAX) GO TO 31
IF (19KG(10,J0+J).NE.0) GO TO 30
19KG(10,J0+J)=1
H(10,J0+J,L)=HDET*HELECT*OTF+TVEFF(10,J0+J,L)
30 CONTINUE
IF (10+1.GT.IMAX) GO TO 31
IF (19KG(10+1,J0+J).NE.0) GO TO 31
19KG(10+1,J0+J)=1
H(10+1,J0+J,L)=HDET*HELECT*OTF+TVEFF(10+1,J0+J,L)
31 CONTINUE
IF (10+1.GT.IMAX) GO TO 32
IF (J0-J.LT.1) GO TO 33
IF (19KG(10+1,J0-J).NE.0) GO TO 32
19KG(10+1,J0-J)=1
H(10+1,J0-J,L)=HDET*HELECT*OTF+TVEFF(10+1,J0-J,L)
32 CONTINUE
IF (J0-J.LT.1) GO TO 33
IF (10-1.LT.1) GO TO 34
IF (19KG(10-1,J0-J).NE.0) GO TO 33
19KG(10-1,J0-J)=1
H(10-1,J0-J,L)=HDET*HELECT*OTF+TVEFF(10-1,J0-J,L)
33 CONTINUE
IF (J0+J0.GT.JMAX) GO TO 34
IF (19KG(10-1,J0+J).NE.0) GO TO 34
19KG(10-1,J0+J)=1
H(10-1,J0+J,L)=HDET*HELECT*OTF+TVEFF(10-1,J0+J,L)
34 CONTINUE
IF (1+10-1.AND.J.EQ.1) H(10,J0,L)=HDET*HELECT*OTF+TVEFF(1,1,L)
IF (10-1.LT.1) GO TO 35
IF (19KG(10-1,J0).NE.0) GO TO 35
19KG(10-1,J0)=1
H(10-1,J0,L)=HDET*HELECT*OTF+TVEFF(10-1,J0,L)
35 IF (J0-J.LT.1) GO TO 36
IF (19KG(10,J0-J).NE.0) GO TO 36
19KG(10,J0-J)=1
H(10,J0-J,L)=HDET*HELECT*OTF+TVEFF(10,J0-J,L)
36 CONTINUE
1516H-1
NUMBER=1
CALL FIX (1516H,NUMBER,EFF(1,1,L))

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C
IF (INUG.NE.0) CALL SCALR (EFF(1,1,1),L,L,LEVEL(5))
DO INVERSE TRANSFORM
FIRST=.FALSE.
DO 37 I=1,IMAX
DO 37 J=1,JMAX
EFF(I,J,L)=EFF(I,J,L)/PRD
ICOUNT=ICOUNT+1
IF (ICOUNT.GE.500) ICOUNT=1
EFF(I,J,L)=EFF(I,J,L)*(ICOUNT)*VNOISE
37 CONTINUE

IF (INUG.NE.0) CALL SCALR (EFF(1,1,1),L,L,LEVEL)
FIND OUT WHAT EACH DETECTOR SEES.
DO 39 IN=1,INL
DO 38 JX=1,JMAX
YI=(DY/2.)*(IN-1)+(DY-DVL)
II=YI/YC+1
YNEU(JX)=VEFF(II,JX,1)
38 CONTINUE
WRITE (12) (YNEU(JX),JX=1,JMAX)
39 CONTINUE
40 CONTINUE
IF (1.GT.TMAX) STOP
GO TO 24

E
41 FORMAT (1X,14HAKKAY SIZE ,3H1=,15,5H J=,15)
42 FORMAT (1X,48HTRAJ MODE NO BANDS LOW BOUND(MICKONS) UPPER BND(MICK
IONS) TARGET NAME/1X4X12,8X14,9XF10.3,8XF10.3,3XAB/2(25XF10.3,9XF10
2.3//)
43 FORMAT (1X,76H MODEL ATM HAZE OPT PATH TYPE EMISS NSAT ELV SENSOR(
IN) INCREMENT(MICKONS)/1X3X12,7X11,8X12,8X12,2X11,5XF10.2,3X,3F1
20.5//)
44 FORMAT (/20X,85HSCAN TIME(SEC) OPTICS DIA(M) DETECTOR WIDTH(M) DET
ECTOR LENGTH(M) DETECTOR OVERLAP(M)/15X,F15.3,1X,F15.3,2X,E15.4,3X
2,E15.4,4X,E15.4/5X,98HFOCAL LENGTH(M) CUTOFF FREQ.(HZ) BACKGROUND
30 ELV(DEG) RMS NOISE LEVEL(V) PEAK RESPONSIVITY(V/W),24H PEAK D
45HARC(W/HZ+2/W)/1X,F15.3,2(3X,F15.3),3(6X,E15.3))
45 FORMAT (1H0)
46 FORMAT (1H0,75H WAVELENGTH OPTICAL DETECTIVITY RES
IPONSIVITY SOLAR IRRAD/75H (MICKONS) TRANSMISSION (CN/
2H+2/W) (V/W) (W/CN+2))
47 FORMAT (1X5(E10.3,6X))
48 FORMAT (/45X,30H+*** TARGET INFORMATION +***,7/15X,95HINIT. RANG
1E(M) VELOCITY(M/SEC) DIAMETER(M) LENGTH(M) INCLIN POSITION(DEG)
2 PHI POSITION(DEG),7/1X,F10.3,6X,F10.3,5X,F10.3,2X,F10.3,5X,F10.3
3,5X,F10.3/23X,77HNOISE LENGTH(M) TAIRPFE DIA(M) TAIRPFE TEMP(K
4) NOISE TEMP(K) SKIN TEMP(K),7/25X,F10.3,5XF10.3,8XF10.3,2X10.3,4
5XF10.3/30X,59HNOISE EMISSIVITY SKIN EMISSIVITY TAIRPFE EM
5155V1011,7/33X,F10.3,10X,F10.3,13X,F10.3/35X,50HVELU ANGLE(DEG)
7 MAX. ENCODER TIME(SEC),/30X,F10.3,17X,F10.3)
49 FORMAT (/48X,27H+*** SUN INFORMATION +***,7/44X,31HATTITUDE(DEG)
1 LONGITUDE(DEG)/46XF10.3,10X,F10.3/44X,33HROUTH DAY A 49H

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2 HOOK/45X13,11X13.0,10X13.0/50X,25HOUR BEARING L.O.S.  
30EG) /55X,10.3) A 499  
50 FURNAT (IX,13HIGI RANGE(M),E13.4,13H 161 VOLTAGE ,2E13.4) A 500  
51 FURNAT (IX,10HAT TIME" ,F10.5,17H TARGET SIZE IS ,E12.4,6H 50 H A 501  
1) A 502  
52 FURNAT (IS,4F10.3) A 503  
53 FURNAT (415,4F10.3,15) A 504  
54 FURNAT (215,2E10.3,48) A 505  
55 FURNAT (111,10X,21HUNORMALIZED BACKGROUND/IX,111J,3X6412/64(IX,111,I A 506  
12,1X6412/)) A 507  
56 FURNAT (110,10X,10HBACKGROUND/IX,111J,3X6412/64(IX,111,I,12,1X6412/)) A 508  
57 FURNAT (IX,44H KEY (DEG K) ENISS AND RANGE(M)) A 509  
58 FURNAT (IX12,4F10.3) A 510  
59 FURNAT (111,10X566) A 511  
60 FURNAT (1515) A 512  
61 FURNAT (566,15) A 513  
END A 514  
A 515

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C 21

REAL FUNCTION INTERP (X,Y,M,ARG)
THIS FUNCTION INTERPOLATES THE GIVEN CURVE FOR ANGULAR DEPENDENCE
OF PLUME INTENSITY.
DIMENSION X(12), Y(12)
IF (X(1).LT.X(M)) GO TO 2
IF (ARG.LT.X(M)) GO TO 5
IF (ARG.GT.X(1)) GO TO 4
DO 1 I=1,M
IF (ARG-X(1)) 1,6,7
1 CONTINUE
GO TO 5
2 IF (ARG.LT.X(1)) GO TO 5
DO 3 I=1,M
IF (X(1)-ARG) 3,6,7
3 CONTINUE
4 INTERP=Y(M)
RETURN
5 INTERP=Y(1)
RETURN
6 INTERP=Y(1)
RETURN
7 INTERP=(Y(1)+(Y(1)-Y(I-1))*(ARG-X(I-1))/(X(I)-X(I-1)))
RETURN
END

SUBROUTINE INTER
THIS ROUTINE READS IN THE FOLLOWING IJP, IGTAU, TAUO, KD, SR AS
FUNCTIONS OF WAVELENGTHS. THE WAVELENGTHS OF INTEREST ARE ISOLATED
AND UP TO 3 CURVES ARE CALCULATED USING LINEAR INTERPOLATION
COMMON /INTP/ YNEW(100,3), IFLAG,M
COMMON /CLDS/ XX(200), YY(200)
COMMON /INTG/ NPU(3), IL, BU(3), BL(3), DV, CV(3), NBANDS
COMMON /CONST/ MODEL, IHAZE, ITYPE, JENIS, JIS, NSAT, DAVEL(100,3)
DIMENSION DVI(3)
IF (IFLAG.GE.5) GO TO 1
READ (5,9) M
IF (IFLAG.EQ.0) READ (5,8) (XX(I),YY(I),I=1,M)
IF (IFLAG.EQ.1) READ (5,7) (XX(I),YY(I),I=1,M)
IF (IFLAG.GE.2) READ (5,10) (XX(I),YY(I),I=1,M)
1 CONTINUE
IFLAG=IFLAG+1
DO 5 I=1,NBANDS
10-NPU(I)
DO 5 M=1,1,M
XLAB=DAVEL(MH,I)
IF (XLAB.GT.XX(I)) GO TO 2

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YMEU(NM,L)=YY(I)
GO TO 5
2 IF (XLM.LT.XX(N)) GO TO 3
YMEU(NM,L)=YY(N)
GO TO 5
3 CONTINUE
DO 4 J=2,M
IF (XLM.GT.XX(J)).OR.(XLM.LT.XX(J-1)) GO TO 4
YMEU(NM,L)=YY(J-1)+((XLM-XX(J-1))/(XX(J)-XX(J-1)))*((YY(J)-YY(J-1))
1)
4 CONTINUE
5 CONTINUE
6 CONTINUE
7 FORMAT (9X F7.4,52X F6.4)
8 FORMAT (4(F12.3,E8.2))
9 FORMAT (15)
10 FORMAT (BE10.3)
END
SUBROUTINE SCALE (EFF,L,LABEL)
THE ROUTINE SCALES THE 64 BY 64 ARRAY AND REPRESENTS IT AS
DIMENSION LABEL(4)
DIMENSION EFF(64,64,1)
DIMENSION IRRG(64,64)
COMMON /PRT1/ IRRG,JMAX,IMAX
COMMON /PRT1/ NG(40,2),NOGLT
COMPLEX EFF
AVER=0.
XMAX=0.
XMIN=1.E+99
DO 1 I=1,IMAX
DO 1 J=1,JMAX
DO 1 K=1,NOGLT
IF (1.EQ.NG(K,1)).AND.(J.EQ.NG(K,2)) GO TO 1
A=SQRT(REAL(EFF(I,J,1))+2*AIMAG(EFF(I,J,1))+2)
IF (A.LT.XMIN) XMIN=A
IF (A.GT.XMAX) XMAX=A
1 CONTINUE
2 CONTINUE
DO 3 I=1,40
EX=10.*(1-I)
IF (XMIN.GE.100.) EX=1./EX
IF (XMIN*EX.GE.1..AND.XMIN*EX.LT.100.) GO TO 4
3 CONTINUE
4 CONTINUE
DO 5 I=1,44
DO 5 J=1,64
5 IRRG(I,J)=EX*SQRT(REAL(EFF(I,J,1))+2*AIMAG(EFF(I,J,1))+2)
WRITE (6,4) LABEL,EX,I,(J,J=1,JMAX),(I,IRRG(I,J),J=1,JMAX),I=1,IM
1AX)
IF (XMAX*EX-XMIN*EX.LE.91) RETURN

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1000-1000
DO 10 2
RETURN

5 FORMAT (MI, JAB, NSH SCALE FACTOR= ,E9.2,15H INTERVAL NO. ,12/1X,1
MI, JAB,12/54(1X,MI,12,1X,12/1)
END

SUBROUTINE ITRAJK
C THIS ROUTINE CALCULATES THE RANGE AND POSITION OF THE TARGET AS A
C FUNCTION OF TIME.
COMMON /ITRA/ NS,VI,DT,IL,ELVS,THIATS,PHITS,TF,MODET,II,JJ,K,ASPE
ICR,K,I,REAROR
COMMON /PNT/ BKG(54,54),JMAX,IMAX
I=1
IF
K=NS-VI+I
II=1000.-(ELVS+THIATS)*FLOAT(IMAX)/10.)*5.1.
JI=500.-(PHITS-1.5707)*FLOAT(JMAX)/2.1.
IF (II.GT.IMAX.OR.JJ.GT.JMAX) WRITE (6,1)
IF (II.GT.IMAX.OR.JJ.GT.JMAX) IERROR=1
IF (II.LT.1.OR.JJ.LT.1) WRITE (6,1)
IF (II.LT.1.OR.JJ.LT.1) IERROR=1
RETURN

1 FORMAT (IX,24HERROR ON TARGET POSITION)
END

SUBROUTINE INTEG
C THIS ROUTINE USES A SIMPLE TRAPEZOIDAL INTEGRATION METHOD
COMMON /INTE/ NPU(3),L,BUC(3),BL(3)
COMMON /INTF/ Y(100),IFLAG,N,H
INTEGER N
COMMON /CONST/ MODEL,INAE,ITYPE,IEMIS,MS,MSAI,MAVEL(100,3)
MI=N-1
BI=0.
SUM1=0.
SUM2=0.
DO 1 I=1,MI
BX=MAVEL(I+1,1)-MAVEL(I,1)
BX=ABS(BX)
SUM1=SUM1+BX*Y(I)
SUM2=SUM2+BX*Y(I+1)
1 CONTINUE
Y(I)=(SUM1+SUM2)/2.
RETURN

END

SUBROUTINE FIX (ISIGN,NUMBER,U)
C THIS ROUTINE CALLS THE FAST FOURIER TRANSFORM AND REORDERS THE
C RESULT OF THE TRANSFORMATION.
COMMON /FAT/ IKG(54,54),JMAX,IMAX,NDIG
DIMENSION M(54,54)

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COMPLEX U
DIMENSION LVEL(16)
COMPLEX A1,A2,A3,A4
DATA LVEL/15,BH
NH(1)=IMAX
NH(2)=JMAX
MLN=64
MLH=MLN/2
CALL FOURT (U,NH,2,ISGN,NUMBER,BUNB)
DO 1 I=1,MLH
DO 1 J=1,MLH
IF=1+MLH
JP=J+MLH
A1=U(I,J)*NOBB(I+J)
A2=U(IP,JP)*NOBB(IP+JP)
A3=U(I,JP)*NOBB(I+JP)
A4=U(IP,J)*NOBB(IP+J)
U(I,J)=A2
U(IP,JP)=A1
U(IP,J)=A3
U(I,JP)=A4
1 CONTINUE
RETURN
END
SUBROUTINE SKYCLD
THE ROUTINE READS IN THE RADIANCE DUE TO CLOUDS, LOCATES THE SUN
OBSERVER AND CLOUD CALCULATES THE SIMULATED VOLTAGE DUE TO CLOUD,
CLEAR SKY, AND HAZE.
COMMON /CLDS/ ZK(200),XK(200)
DIMENSION YK(8)
DIMENSION SZK(2,7),AZK(2,7),VA(2,7)
DIMENSION NJ(8),NJ(8),XINT(3)
COMMON /INTG/ MFC(3),AL,BU(3),BL(3),DV(3),CV(3),NBANDS
COMMON /LOW/ LAMB(100),AFK(100)
COMMON /INTF/ DUN(300),IFLAG,LA,HH
COMMON /RESI/ TOTRAM,I21,I22,I23,I24,I25,I26,I27,I28,I29,I30,I31
I,I212,K21,K22,K23,K24
COMMON /ANG/ THU,PH,THN,PHN,ALT,TKUEB
COMMON /GLI/ KLA1,KLONG,MON,DAY,HR,THL,FHL,I01,I02,I03,I04,I05,I06
I,KD(100,3),LAMB(100,3),XLAMB(3),XLAMB(3),VEFF(54,5,3),TIMEI
DIMENSION CLD(100,3)
COMMON /ITKNI/ NS,TV,BT,TL,ELVS,INITATS,PHITS,IF,MODE1,I,I,J,K,NSPE
I01,I,AT,IEKKOK,I(100,3)
COMMON /INTF/ TB(40),EB(40),KND(40),KEY(40),LDT(100,3),SHCI
I00,3,I01(100,3)
COMMON /CONST/ MODEL,INAZE,I1TYPE,IEMIS,NS,NSAI,NAVEL(100,3)
COMMON /MISC/ D,FL,C1,C2,DEGRAD,NI,N2
DIMENSION THEU(100,3),TOTRAM(2000)
EQUIVALENCE (DUN(1),THEU(1,1))
COMPLEX VEFF

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DATA (STA(1,J),J=1,7)/0.,15.,30.,45.,60.,75.,90.,
DATA (AZA(1,J),J=1,5)/0.,45.,90.,135.,180./
DATA (VAL(1,J),J=1,7)/0.,15.,30.,45.,60.,75.,90.,
DATA (VAL(2,J),J=1,6)/0.,2.,4.,6.,8.,10./
DATA (STA(2,J),J=1,6)/0.,2.,4.,6.,8.,10./
DATA (AZA(2,J),J=1,5)/0.,45.,90.,135.,180./
DATA YK/2.,3.,4.,5.,6.,8.,10.,14./
DO 1 I=1,8
1 ZK(I)=YK(I)
KK=IC1
LM=8
CALL SUMLOC
THL=180.*DEGRAD-ELVS
XLUS=90.*DEGRAD-ALT
THO=0.
TH=ABS(XLUS-ELVS)
PH=ABS(THOEB-PHL)
NORM=1
IF (IC1.EQ.0) GO TO 2
IC=1
NORM=1
GO TO 11
2 IF (IC6.NE.0) GO TO 3
CALL DUMK
IF (IC4.NE.0) GO TO 5
CALL DUMK
IF (IC5.NE.0) GO TO 7
CALL DUMK
IF (IC2.NE.0) GO TO 8
CALL DUMK
IF (IC3.NE.0) GO TO 9
RETURN
3 CONTINUE
READ (5,33) NORM
KK=IC6
IC=6
IC6=0
4 CONTINUE
N=1
LJA=245
IC1=7
ICJ=5
ICK=7
GO TO 10
5 CONTINUE
KK=IC4
IC=4
IC4=0
6 CONTINUE
N=2
LJA=180

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DO 18 I=1,NBANDS
  LA=NPUL(I)
DO 18 I=1,LM
  18 CLD(I,L)=YNEW(I,L)
19 CONTINUE
DO 23 L=1,NBANDS
  LL=L
  M1=XLARL(L)
  M2=XLARU(L)
  VV=VV(L)
  S=KB(KK)+.001
  M1=M2+EOS(EIVS)*KB(KK)+.001
  J=10
  LA=NPUL(L)
  CALL LOUEN (MODEL, IHAZE, ITYPE, IZ1, IZ2, IZ3, IZ4, IZ5, IZ6, IZ7, IEMIS, KZ
  11, M1, M2, KZ2, S, KZ3, KZ4, M1, M2, VV, IZ6, J, IZ6, IZ10, IZ11, IZ12, IO(KAN, 200
  20, NSAI)
DO 20 I=1,LM
  20 DUM(I)=APR(I)+TAUD(I,L)+KB(I,L)
  CALL INIEG
  XINT(L)=DUM(I)*10.
  IF (IC.NE.1) GO TO 21
  XINT(L)=XINT(L)+D+PI+.00000001
  GO TO 23
21 DO 22 I=1,LM
  22 DUM(I)=CLD(I,L)+TAUD(I,L)+KB(I,L)+IADA(I)
  CALL INIEG
  XINT(L)=(XINT(L)+DUM(I))*PI+D+.00000001
23 CONTINUE
  IF (MOELS.NE.0) GO TO 25
  READ (5,32) ICHIN, ICHAX, JCHIN, JCHAX
DO 24 I=1,NBANDS
DO 24 J=1,ICHIN, ICHAX
DO 24 J=JCHIN, JCHAX
  24 VEFF(I,J,L)=XINT(L)
  GO TO 29
25 CONTINUE
DO 28 I=1,MOELS,8
  READ (5,32) NI(K), NJ(K), K=1,8)
DO 27 L=1,NBANDS
DO 26 K=1,8
  IF (NI(K).EQ.0) GO TO 27
  26 VEFF(NI(K), NJ(K), L)=XINT(L)
27 CONTINUE
28 CONTINUE
29 CONTINUE
30 CONTINUE
  KEND=8
  GO TO 2
31 FORMAT (2E10.3)

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32 FORMAT (I4I5)
33 FORMAT (I5,2E10.3)
34 FORMAT (6X8E9.4)
END
SUBROUTINE DUNK
C THIS ROUTINE DUNKY HEADS THE CLOUD RADIANCE RECORDS FOR THOSE NOT
C USED.
1 CONTINUE
READ (8,3) IA
IF (EDF(8)) 2,1
2 RETURN
C
3 FORMAT (A1)
END
SUBROUTINE IGISIG
REAL BLKDY
REAL INTERP
COMMON /ITRAJ/ RS,TV,BI,TL,ELVS,INTATS,PHITS,IF,MODET,II,J,J,K,ASPE
ICT,1,AT,IERKOK,TJ(100,3)
COMMON /INTG/ NPU(3),LL,BU(3),DV(3),CV(3),NBANDS
COMMON /MISS/ INL,IPL,DP,IE,IM,IS,ETM,ETS,ETE
COMMON /POST/ ANGLE(12),FUNC(12)
COMMON /INFT/ TB(40),EB(40),KHD(40),KB(40),KEY(40),TJP(100,3),SR(1
100,3),IGTAU(100,3)
COMMON /CONST/ MODEL,INAZE,ITYPE,IEMIS,HS,MSAI,NAVEL(100,3)
COMMON /MISC/ D,PI,C1,C2,DEGRAD,M1,H2
C THIS ROUTINE CALCULATES THE TOTAL TARGET SIGNATURE AND PRESENTED
C AREA.
FACTN=1.
FACTOR=0.
WRITE (5,2)
FACTN=COS(ASPECT*DEGRAD)
IF (ASPECT.GE.90.) FACTN=0.
IF (ASPECT.GE.90.) FACTOR=COS(ASPECT*DEGRAD)
AT=0.
FP=INTERP(ANGLE,FUNC,12,ASPECT)
AE=DP*DP*PI*.25*FACTOR*(-1.)+1.E+04
ASPECTR=ASPECT*DEGRAD
AN=PI*DI*DI*.25*FACTN*DI*INL+.5*SIN(ASPECTR)
AN=AN+1.E+04
AS=TL*DI*SIN(ASPECTR)+10000.
DO I=1,NBANDS
LN=NPU(I)
DO J=1,LM
XL=NAVEL(I,1)
II=IE
IEMN=ETE*BLKDY(I,XL,C1,C2)/PI
FMT=IEMN*IGTAU(I,1)*AE
II=IM
IEMN=EM*BLKDY(I,XL,C1,C2)/PI
FMT2=IEMN*AN

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11-15
JENK-ETS=BLKBDY(11,X1,C1,C2)/PI
PAK3=TERM*AS
PAK4=LUP(1,1)*FP
1J(1,1)=PAK1*PAK2*PAK3*PAK4
WRITE (6,3) WAVE(1,1),PAK2,PAK3,PAK1,PAK4,1J(1,1)
1 CONTINUE
AN=AN+.0001
AS=AS+.0001
AE=AE+.0001
AT=AN*AS*AE
WRITE (6,4) AN,AS,AE,AT
RETURN

C
2 FORMAT (1X,34)TARGET SIGNATURE(WAVE/SIG/MIKRO)/5X,BOW MIDDONS
1 NOSE BODY TAILPIPE PLUME TO
2AL/ )
3 FORMAT (1X6(F10.3,5X))
4 FORMAT (1H0,5X,11)AREAS(M*2)/5X,51H NOSE BODY
1 TAILPIPE TOTAL/1X4(F10.2,5X))
END
REAL FUNCTION BLKBDY (TT,X1,C1,C2)
THIS FUNCTION FINDS THE BLACK BODY RADIATION.
IF (TT.LE..1) GO TO 1
BLKBDY=C1/(X1+.5*(EXP(C2/(X1*TT))-1.))
RETURN
1 BLKBDY=0.
RETURN
END

SUBROUTINE FIND (TH0,ICI,SZA,J1,J2,B)
THIS ROUTINE FINDS THE TWO CURVES OF PATH RADIANCE FOR INTERPOLA
TION.
DIMENSION SZA(8)
J1=0
DO 1 I1=1,ICI
IF (TH0.GT.SZA(I1)) GO TO 1
IF (TH0.EQ.SZA(I1)) GO TO 2
J2=I1
GO TO 3
1 J1=I1
J1=ICI
B=(TH0-SZA(J1))/(SZA(J2)-SZA(J1))
J2=J1
RETURN
GO TO 3
2 J1=J2=I1
B=0.
RETURN
3 CONTINUE
IF (J1.EQ.0) GO TO 2
B=(TH0-SZA(J1))/(SZA(J2)-SZA(J1))

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KH-KAHF(A)
DO 4 M=1,MGLI
IF (KH.LE.FSG) GO TO 4
VEFF(NG(M,1),NG(M,2),L)=VEFF(NG(M,1),NG(M,2),L)+VGLMT(M,1)
4 CONTINUE
RETURN
5 FORMAT (B10.3)
6 FORMAT (1615)
7 FORMAT (15,E10.3)
END

```

C





4-26

[illegible]

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```

20 HURP=NP2/NIUD
  ICASE=1
  IFIN=1
  IIRG=NP1
  IF (IDN-4) 74,100,100
74 IF (IFUR) 71,71,100
71 ICASE=2
  IIRG=NP0*(1+NP2/2)
  IF (IDN-1) 22,22,100
72 ICASE=3
  IIRG=NP1
  IF (NIUD-NP1) 100,100,73
73 ICASE=4
  IFIN=2
  NIUD=NIUD/2
  N=N/2
  NP2=NP2/2
  NIOT=NIOT/2
  I=1
  DO 80 J=1,NIOT
    DATA(J)=DATA(I)
  DO 1-1+2
  DO 100 IF (HURP-1) 101,101,200
  101 NP2HF=NP2/2
  J=1
  DO 150 I2=1,NP2,NP1
    IF (J-12) 121,130,130
  121 IIRAX=I2+NP1-2
  DO 125 I1=12,IIRAX,2
  DO 125 I3=11,NIOT,NP2
  J3=J+I3-I2
  IENR=DATA(I3)
  IENP1=DATA(I3+1)
  DATA(I3)=DATA(J3)
  DATA(I3+1)=DATA(J3+1)
  DATA(J3)=IENR
  DATA(J3+1)=IENP1
  125 DATA(J3+1)=IENP1
  130 N=NP2HF
  140 IF (J-H) 150,150,141
  141 J=J-H
  N=N/2
  IF (N-H) 150,140,140
  150 J=J+H
  GO TO 300
200 HURK=2*N
  DO 270 I1=1,NP1,2
  DO 270 I3=11,NIOT,NP2
  J=13
  DO 260 I=1,HURK,2
  IF (ICASE-3) 210,220,210
  210 HURK(I)=DATA(I)

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WORK(1:1)=DATA(J:1)
6010 240
220 WORK(1)=DATA(J)
240 WORK(1:1)=0.0
240 IFP2=NP2
IF=IFMIN
250 IFP1=IFF2/IFACT(IF)
J=J+IFP1
255 J=J-IFP2
IFP2=IFP1
IF=IF+1
IF(IFP2-NP1)260,260,250
260 CONTINUE
I2MAX=I3+NP2-NP1
I=I
60 270 I2=I3,I2MAX,NP1
DATA(I2)=WORK(I1)
DATA(I2+1)=WORK(I1+1)
270 I=I+2
300 IF(MTUO-NP1)600,600,305
305 NP1U=NP1-NP1
IPAR=MTUO/NP1
310 IF(IPAR-21350,330,320)
320 IPAR=IPAR/4
6010 310
330 60 340 I1=1,I1KNG,2
60 340 K1=I1,MTOT,NP1U
K2=K1+NP1
TEMPK=DATA(K2)
TEMP1=DATA(K2+1)
DATA(K2)=DATA(K1)-TEMPK
DATA(K2+1)=DATA(K1+1)-TEMP1
DATA(K1)=DATA(K1)+TEMPK
340 DATA(K1+1)=DATA(K1+1)+TEMP1
350 MAX=NP1
360 IF(MMAX-MTUO/21370,600,600)
370 LMAX=MAX0(NP1U,MMAX/2)
60 570 L=NP1,LMAX,NP1U
M=L
IF(MMAX-NP1)420,420,380
380 THETA=-100*PI*DATA(1)/FLOAT(4+MMAX)
IF(1516N)400,390,390
390 THETA=-THETA
C 400 WK=COS(THETA)
C 400 WK=SIN(THETA)
400 WK=COS(THETA)
410 WK=SIN(THETA)
410 WK=WK+WK-MT*UI
420 WK=2.0*WK+UI
430 WK=0.2R*WK-0.21*UI

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431 02K=01+021+02K
420 00 530 11=1,11K05,2
      K101=11+1P0K+01
      IF (MMAX-NP1)430,430,440
430 K101=11
440 K01F=1P0K+MMAX
450 K51EF=0+K01F
      IF (K51EF-N100)460,460,530
460 00 520 K1-K101,0101,K51EF
      K2-K1+K01F
      K3-K2+K01F
      K4-K3+K01F
      IF (MMAX-NP1)470,470,480
470 01K=DATA(K1)+DATA(K2)
      011=DATA(K1+1)+DATA(K2+1)
      02K=DATA(K3)+DATA(K4)
      021=DATA(K3+1)+DATA(K4+1)
      03K=DATA(K1)-DATA(K2)
      031=DATA(K1+1)-DATA(K2+1)
      IF (15100)471,472,472
471 04K=DATA(K3+1)-DATA(K4+1)
      041=DATA(K4)-DATA(K3)
      0010 510
472 04K=DATA(K4+1)-DATA(K3+1)
      041=DATA(K3)-DATA(K4)
      0010 510
480 12K=02K+DATA(K2)-021+DATA(K2+1)
      121=02K+DATA(K2+1)+021+DATA(K2)
      13K=03K+DATA(K3)-01+DATA(K3+1)
      131=03K+DATA(K3+1)+01+DATA(K3)
      14K=03K+DATA(K4)-031+DATA(K4+1)
      141=03K+DATA(K4+1)+031+DATA(K4)
      03K = DATA (K1)-12K
      011 = DATA(K1+1)+121
      03K = 13K+14K
      031 = DATA(K1+1)-121
      01K = DATA(K1)+12K
      021 = 131+141
      IF (15100)490,500,500
490 04K=131-141
      041=14K-13K
      0010 510
500 04K=141-131
      041=13K-14K
510 DATA(K1)=01K+02K
      DATA(K1+1)=011+021
      DATA(K2)=02K+04K
      DATA(K2+1)=021+041
      DATA(K3)=03K+02K
      DATA(K3+1)=031+021
      DATA(K4)=04K+04K

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520 DATA(11)-U31,U41
    KDF=KSTEP
    KTR=4*(KMIN-11)+11
    GOTO 450
530 CONTINUE
    A=PI*MAX
    IF (A-NDAX)540,540,570
540 IF (ISIGN)550,550,560
550 TEMPR=UK
    UK=(UK-UI)*KTHLF
    UI=(UI-TEMPR)*KTHLF
    GOTO 410
560 TEMPR=UK
    UK=(UK-UI)*KTHLF
    UI=(TEMPR-UI)*KTHLF
    GOTO 410
570 CONTINUE
    IFAR=3-IPAR
    NHAX=NHAX+NHAX
    GOTO 360
600 IF (NON2P-1)700,700,601
601 IFPI=NIUO
    IF=IMON2
610 IFP2=IFACT(1F)*IFPI
    THETA=-TUOF1/FLOAT(1F*FACT(1F))
    IF (ISIGN)612,611,611
611 THETA=-THETA
612 USTPR=COS(THETA)
    C    USTPI=SIN(THETA)
612 USTPR=COS(THETA)
    USTPI=SIN(THETA)
60 650 J1=J,IFPI,NF1
    THETA=-TUOF1/FLOAT(J1-1)/FLOAT(IFP2)
    IF (ISIGN)614,613,613
613 THETA=-THETA
614 UNHPR=COS(THETA)
    C    UNHPI=SIN(THETA)
614 UNHPR=COS(THETA)
    UNHPI=SIN(THETA)
    J1MAX=J1+1/NKG-2
60 650 I1=J1,I1MAX,2
60 650 I3=I1,NIOT,NF2
    I=1
    UK=UNHPR
    UI=UNHPI
    J2MAX=J3+IFP2-IFPI
60 640 J2=J3,J2MAX,IFPI
    TUOUK=UK+UK
    J3MAX=J2+IFP2-IFP2
60 630 J3=J2,J3MAX,IFP2
    JMIN=J3-J2+13
    J35

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J=JMIN+IFF2-IFPI
SR=DATA(J)
SI=DATA(J+1)
OLDSR=0.0
OLDSI=0.0
J=J-IFPI
420 SINR=SR
    SINPI=SI
SR=1000K+SR-OLDSR+DATA(J)
SI=1000K+SI-OLDSI+DATA(J+1)
OLDSR=SR
OLDSI=SI
J=J-IFPI
    IF (J-JMIN)621,621,620
621 WORK(I)=UR+SR-UI+SI-OLDSR+DATA(J)
    WORK(I+1)=UI+SR+UR+SI-OLDSI+DATA(J+1)
630 I=I+2
    VIENP=UR+USIPI
    UR=UR+USIPR-UI+USIPI
    VI=VI+UI+USIPR+VIENP
    I=I
DO 450 J2=J3,J2MAX,IFPI
J2MAX=J2+NP2-IFP2
DO 450 J3=J2,J3MAX,IFP2
DATA(J3)=WORK(I)
DATA(J3+1)=WORK(I+1)
650 I=I+2
    IF-IF+1
    IFPI=IFF2
    IF (IFPI-NP2)610,700,700
700 GO TO 690,800,900,701,ICASE
701 MHALF=N
    N=N+M
    THETA=-100PI/FLOAT(N)
    IF (ISIGN)703,702,702
702 THETA=-THETA
C 703 USIPR=COS(THETA)
C    USIPI=SIN(THETA)
703 USIPR=COS(THETA)
    USIPI=SIN(THETA)
    UR=USIPR
    UI=USIPI
    IAIN=3
    JMIN=2+MHALF-1
    GO TO 725
710 J=JMIN
DO 720 I=JMIN,NIOT,NP2
    SUNK=(DATA(I)+DATA(J))/2.0
    SUNI=(DATA(I+1)+DATA(J+1))/2.0
    DIFR=(DATA(I)-DATA(J))/2.0
    DIFI=(DATA(I+1)-DATA(J+1))/2.0

```



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TEMPR=UK+SUNT*UI*UIFK
TENPI=UI+SUNT*UK*UIFK
DATA(I)=SUNT*TEMPR
DATA(I+1)=DIF1*TEMPI
DATA(J)=SUNT*TEMK
DATA(J+1)=DIF1*TEMPI
720 J=JNP2
IMIN=IMIN+2
JMIN=JMIN-2
UTEMP=UK*USUPI
UK=UK*USIFK*UI*USUPI
UI=UI*USIFK*UTEMP
725 IF(IJMIN-JMIN)710,730,740
730 IF(1SIGN)731,740,740
731 DO 735 1=IMIN,NIOI,NP2
735 DATA(I+1)=-DATA(I+1)
740 NP2=NP2+NP2
NIOI=NIOI+NIOI
J=NIOI+1
IMAX=NIOI/2+1
745 IMIN=IMAX-2*HALF
J=JMIN
GO TO 755
750 DATA(J)=DATA(I)
DATA(J+1)=-DATA(I+1)
755 J=J+2
J=J-2
IF(I-IMAX)750,760,760
760 DATA(J)=DATA(IMIN)-DATA(IMIN+1)
DATA(J+1)=0.0
IF(I-J)770,780,780
785 DATA(J)=DATA(I)
DATA(J+1)=DATA(I+1)
790 1=1-2
J=J-2
IF(I-IMIN)775,775,765
775 DATA(J)=DATA(IMIN)+DATA(IMIN+1)
DATA(J+1)=0.0
IMAX=IMIN
GO TO 745
780 DATA(1)=DATA(1)+DATA(2)
DATA(2)=0.0
GO TO 900
800 IF(IIRNG-NP1)805,900,900
805 DO 860 13=1,NIOI,NP2
12MAX=13+NP2-NP1
DO 850 12=13,12MAX,NP1
IMIN=12+IIRNG
IMAX=12+NP1-2
IMAX=2+13+NP1-IMIN
IF(12-13)820,820,810

```

```

IRSTA 1217
IRSTA 1218
IRSTA 1219
IRSTA 1220
IRSTA 1221
IRSTA 1222
IRSTA 1223
IRSTA 1224
IRSTA 1225
IRSTA 1226
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IRSTA 1245
IRSTA 1246
IRSTA 1247
IRSTA 1248
IRSTA 1249
IRSTA 1250
IRSTA 1251
IRSTA 1252
IRSTA 1253
IRSTA 1254
IRSTA 1255
IRSTA 1256
IRSTA 1257
IRSTA 1258
IRSTA 1259
IRSTA 1260
IRSTA 1261
IRSTA 1262
IRSTA 1263
IRSTA 1264
IRSTA 1265
IRSTA 1266
IRSTA 1267

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810 JMAX=JMAX\*NP2  
820 IF (I-IH-2) 850, 850, 850  
830 J=JMAX\*NP0  
840 I=I-IH, IMAX, 2  
DATA(I)=DATA(J)  
DATA(I+1)=-DATA(J+1)  
840 J=J-2  
850 J=JMAX  
860 I=I-IH, IMAX, NP0  
DATA(I)=DATA(J)  
DATA(I+1)=-DATA(J+1)  
850 J=J-NP0  
900 NP0=NP1  
NP1=NP2  
910 NPREV=N  
920 RETURN  
930 CONTINUE  
STOP 50  
RETURN  
END

[illegible]



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FROM 350 CM-1 TO 4000 CM-1 (0.25 TO 20.57 MICRONS) AT 20 CM-1  
SPECTRAL RESOLUTION ON A LINEAR WAVELENGTH SCALE.  
REFRACTION AND EARTH CURVATURE EFFECTS ARE INCLUDED. ATMOSPHERE  
IS ENTERED IN ONE KM. INTERVALS BETWEEN 0 AND 25 KM., 5 KM. THICK-  
NESS TO 50 KM., A TWENTY KM. INTERVAL TO 70 KM., AND A THIRTY KM.  
INTERVAL TO 100 KM.  
PROGRAM ACTIVATED BY SUBMISSION OF FOUR CARD SEQUENCE AS FOLLOWS  
CARD 1 MODEL, IMAZE, ITYPE, IEN, JP, IM, M1, M2, M3, M4, IEMISS, KU FORMAT(101)  
CARD 2 H1, M2, ANGLE, RANGE, BETA, VIS FORMAT(110.3)  
CARD 3 V1, V2, DV FORMAT(110.3)  
CARD 4 IXY FORMAT(113)  
MODEL-1, 2, 3, 4, 5 OR 6 SELECTS ONE OF THE FOLLOWING MODEL ATMOSPHERE  
TROPOCAL, MINIMATITUDE SUMMER, MINIMATITUDE WINTER, SUBARCTIC SUMMER,  
SUBARCTIC WINTER, OR THE 1962 U.S. STANDARD RESPECTIVELY  
MODEL-0 FOR HORIZ. PATH WHEN METEOROL. DATA USED; INSTEAD OF CARD 2  
READ M1, P(ANB), I(DEC C), DEW PT. TEMP(DEC C), REL. HUMIDITY, W20 DENSITY  
(CM-N 3), 03 DENSITY(CM-N 3), VIS(KM), RANGE(KM) WITH FORMAT 429.  
MODEL-7 WHEN NEW MODEL ATMOSPHERE (E.G. RADIOSOUND DATA) USED.  
DATA CARDS ARE READ IN BETWEEN CARDS 1 AND 2, AND SHOULD CONTAIN:  
ALTITUDE(KM.), PRESSURE, TEMP, DEW PT. TEMP, REL. HUMIDITY, W20 DENSITY,  
03 DENSITY, AEROSOL NO. DENSITY(CM-3) ACCORDING TO FORMAT 429.  
NOTE THAT EITHER DEW PT. TEMP OR REL. HUMIDITY CAN BE USED.  
M1, M2, M3, ARE USED TO CHANGE TEMP, W20, AND 03 ALTITUDE PROFILES.  
IF IMAZE=0 NO AEROSOL SCATTERING IS COMPUTED  
IMAZE=1 IF AEROSOL ATTENUATION REQUIRED (THIS IS USED IN  
CONJUNCTION WITH VISUAL RANGE(SEE CARD 2))  
IMAZE=1 OR 2 ALSO GIVE AEROSOL ATTENUATION FOR 23KM AND 5KM VIS.  
IMAZE MODELS RESPECTIVELY IF VIS=0 ON CARD 2  
ITYPE=1, 2 OR 3 INDICATES THE TYPE OF ATMOSPHERIC PATH  
ITYPE=3, VERTICAL OR SLANT PATH TO SPACE  
ITYPE=2, VERTICAL OR SLANT PATH BETWEEN TWO ALTITUDES  
ITYPE=1, CORRESPONDS TO A HORIZONTAL (CONSTANT PRESSURE) PATH  
IEMISS=0 TRANSMITTANCE MODE  
IEMISS=1 RADIANCE MODE  
H1=OBSERVER ALTITUDE (KM)  
H2=SOURCE ALTITUDE (KM)  
ANGLE=ZENITH ANGLE AT H1 (DEGREES)  
RANGE=PATH LENGTH (KM)  
BETA=PATH CENTER ANGLE  
VIS=VISUAL RANGE AT SEA LEVEL (KM)  
(IF ITYPE=1 READ H1 AND RANGE; IF ITYPE=3 READ H1 AND ANGLE.  
IF ITYPE=2 READ H1 AND TWO OTHER PARAMETERS I.E. H2 AND ANGLE)

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1  VI=INITIAL FREQUENCY (H)AVERAGE CM-1 ) (INTEGER VALUE
2  V2=FINAL FREQUENCY (H)AVERAGE CM-1 ) (INTEGER VALUE
3  DV= FREQUENCY INTERVALS AT WHICH TRANSMITTANCE IS PRINTED
4  NOTE: DV MUST BE A MULTIPLE OF 5 CM-1
5
6 *****
7 IXY=0
8 KOUN=0
9 KMAX=11
10 IF (ISF.GT.0) GO TO 10
11 READ (3,400) IATM,ML
12 READ (3,401) (H21(I),I=1,ML)
13 READ (3,401) (H22(I),I=1,5)
14 H22(6)=H21(6)
15 DO 1 J=1,3
16 K2=2+J
17 K1=K2-1
18 DO 1 I=1,ML
19 READ (3,402) Z(I), (C(K,I),T(K,I),WH(K,I),W(K,I),K-K1,K2)
20 READ (3,431) (VX(I),C7(I),C7A(I),I=1,44)
21 READ (3,403) (TK(I),FW(I),FO(I),I=1,67)
22 READ (3,404) (CI(I),I=1,2580)
23 READ (3,404) (C2(I),I=1,1575)
24 READ (3,404) (C3(I),I=1,540)
25 READ (3,405) (C4(I),I=1,133)
26 READ (3,404) (C5(I),I=1,15)
27 READ (3,405) (C6(I),I=1,102)
28
29 16 FI=3.14159265
30 CA=PI/180.
31 IF=0
32 CONTINUE
33 DO 1002 I=1,34
34 DO 1002 J=1,KMAX
35 WXY(I,J)=0.
36 KE=6371.23
37 IFIR=0
38 IF (TEMSS.EQ.1.AND. IURTE.GT.1) WRITE(I,1170)
39 IF (TEMSS.EQ.0.AND. IURTE.GT.1) WRITE(I,1171)
40 IENSTO =LEN
41 IF (IURTE.GT.1) WRITE(I,400) MODEL, IURTE, ITYPE, IEN, JF, IAT, ML, H2
42 I, H3, ML, TEMSS, K0
43 N=MODEL
44 IF (M.EQ.1) KE=6370.37
45 IF (M.EQ.4) KE=6355.91
46 IF (M.EQ.5) KE=6355.91
47 IF (IXY.GT.3) GO TO 0
48 IF (K0.ME.0.0) KE=K0
49 IF (M.EQ.7.AND. IAT.ME.0160 TO 4
50 IF (MODEL.EQ.0) GO TO 4
51 CONTINUE
52 IF (IURTE.GT.1) WRITE(I,425) H1,H2, HROLE, RANGE, BETA, V15

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1  X1=RE*H1
   IF (TYPE.EQ.3) GO TO 530
   IF (TYPE.EQ.1) GO TO 8
   X2=RE*H2
   IF (RANGE.EQ.0.) GO TO 5
   IF (URITE.GT.1) URITE(1,428) H1,H2,ANGLE,RANGE,BETA,VIS
   IF (H2.EQ.0.AND.ANGLE.NE.0) GO TO 3
   ANGLE=ACOS(0.5*(H2-H1)*(1+X2/X1)/RANGE-RANGE/X1)/CA
   GO TO 7
2  X2=SRRT((X1/RANGE+RANGE/X1)+2.0+CDSC(ANGLE*CA))*X1+RANGE)
   H2=X2-K1
   GO TO 7
3  CONTINUE
   IF (H1.E.0)H1=1
   DO 540 K=1,NL
     ANGLE(K)=0.0
     IF (H.EQ.0)XREAD(1,429) H1,P(7,1),IMP,DP,KH,WH(7,K),UD(7,K),
     VIS,RANGE
     IF (H.EQ.0.AND.URITE.GT.1) URITE(1,430) H1,P(7,1),IMP,DP,KH,
     WH(7,K),UD(7,K),VIS,RANGE
     IF (H.GT.0)XREAD 429,Z(K),P(7,K),IMP,DP,KH,WH(7,K),UD(7,K),ANGLE(K)
     J=FIX(Z(K)+1.0E-6)+1.
     IF (H.EQ.0)Z(K)=H1
     IF (Z(K).GE.25.0) J=Z(K)-25.0/5.0+26.
     IF (Z(K).GE.50.0) J=Z(K)-50.0/20.0+31.
     IF (Z(K).GE.70.0) J=Z(K)-70.0/30.0+32.
     IF (J.GT.33)J=33
     FAC=Z(K)-FLOAT(J-1)
     IF (J-1.25) GO TO 500
     FAC=Z(K)-5.0+FLOAT(J-26)-25.)/5.
     IF (J.GE.31) FAC=Z(K)-50.0/20.
     IF (J.GE.32) FAC=Z(K)-70.0/30.
     IF (FAC.GT.1.0) FAC=1.0
     I=J+1
     I(7,K)=IMP+273.15
     IF (H1.GT.0)I(7,K)=I(H1,J)+(I(H1,1)-I(H1,J))*FAC
     I1=273.15/I(7,K)
     IF (KH.E.0.0) I1=273.15/(273.15+DP)
     IF (WH(7,K).E.0.0) WH(7,K)=F(I1)
     IF (H2.GT.0)WH(7,K)=WH(M2,J)*(WH(M2,1)/WH(M2,J))*FAC
     IF (KH.GT.0.0) WH(7,K)=0.01*KH*WH(7,K)
     IF (H3.GT.0)UD(7,K)=UD(M3,J)*(UD(M3,1)/UD(M3,J))*FAC
     IF (Z(K).GE.5.0)GO TO 520
     IF (ANGLE(K).EQ.0.0)AHZ2(K)=H2*(J)*(H22(1)/H22(J))*FAC
     IF (AHAZE(K).EQ.0.0)AHAZE(K)=H1(J)*(H21(1)/H21(J))*FAC
     IF (HDEL.EQ.0)GO TO 8
     IF (H.EQ.0.AND.URITE.GT.1) URITE(1,441)
     IF (URITE.GT.1) URITE(1,429) Z(K),P(7,K),IMP,DP,KH,WH(7,K),
     UD(7,K),AHAZE(K)
     CONTINUE
     GO TO 10-0
500 I=J+1
     I(7,K)=IMP+273.15
     IF (H1.GT.0)I(7,K)=I(H1,J)+(I(H1,1)-I(H1,J))*FAC
     I1=273.15/I(7,K)
     IF (KH.E.0.0) I1=273.15/(273.15+DP)
     IF (WH(7,K).E.0.0) WH(7,K)=F(I1)
     IF (H2.GT.0)WH(7,K)=WH(M2,J)*(WH(M2,1)/WH(M2,J))*FAC
     IF (KH.GT.0.0) WH(7,K)=0.01*KH*WH(7,K)
     IF (H3.GT.0)UD(7,K)=UD(M3,J)*(UD(M3,1)/UD(M3,J))*FAC
     IF (Z(K).GE.5.0)GO TO 520
     IF (ANGLE(K).EQ.0.0)AHZ2(K)=H2*(J)*(H22(1)/H22(J))*FAC
     IF (AHAZE(K).EQ.0.0)AHAZE(K)=H1(J)*(H21(1)/H21(J))*FAC
     IF (HDEL.EQ.0)GO TO 8
     IF (H.EQ.0.AND.URITE.GT.1) URITE(1,441)
     IF (URITE.GT.1) URITE(1,429) Z(K),P(7,K),IMP,DP,KH,WH(7,K),
     UD(7,K),AHAZE(K)
     CONTINUE
     GO TO 10-0
540 I=J+1
     I(7,K)=IMP+273.15
     IF (H1.GT.0)I(7,K)=I(H1,J)+(I(H1,1)-I(H1,J))*FAC
     I1=273.15/I(7,K)
     IF (KH.E.0.0) I1=273.15/(273.15+DP)
     IF (WH(7,K).E.0.0) WH(7,K)=F(I1)
     IF (H2.GT.0)WH(7,K)=WH(M2,J)*(WH(M2,1)/WH(M2,J))*FAC
     IF (KH.GT.0.0) WH(7,K)=0.01*KH*WH(7,K)
     IF (H3.GT.0)UD(7,K)=UD(M3,J)*(UD(M3,1)/UD(M3,J))*FAC
     IF (Z(K).GE.5.0)GO TO 520
     IF (ANGLE(K).EQ.0.0)AHZ2(K)=H2*(J)*(H22(1)/H22(J))*FAC
     IF (AHAZE(K).EQ.0.0)AHAZE(K)=H1(J)*(H21(1)/H21(J))*FAC
     IF (HDEL.EQ.0)GO TO 8
     IF (H.EQ.0.AND.URITE.GT.1) URITE(1,441)
     IF (URITE.GT.1) URITE(1,429) Z(K),P(7,K),IMP,DP,KH,WH(7,K),
     UD(7,K),AHAZE(K)
     CONTINUE
     GO TO 10-0

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1485 1486 1487 1488 1489 1490 1491 1492 1493 1494 1495 1496 1497 1498 1499 1500 1501 1502 1503 1504 1505 1506 1507 1508 1509 1510 1511 1512 1513 1514 1515 1516 1517 1518 1519 1520 1521 1522 1523 1524 1525 1526 1527 1528 1529 1530 1531 1532 1533 1534 1535
1485 1486 1487 1488 1489 1490 1491 1492 1493 1494 1495 1496 1497 1498 1499 1500 1501 1502 1503 1504 1505 1506 1507 1508 1509 1510 1511 1512 1513 1514 1515 1516 1517 1518 1519 1520 1521 1522 1523 1524 1525 1526 1527 1528 1529 1530 1531 1532 1533 1534 1535

C  NOTE THAT Z(I) MAY NOT CORRESPOND TO THE VALUES GIVEN FOR STANDARD
C  MODEL ATMOSPHERES
530  GO TO 300
530  IF (RANGE.GT.0.0) GO TO 580
530  IF (H2.GT.0.0.AND.H2.LT.H1) IFIND=1
530  GO TO 8
580  ITYPE=2
580  BETA=ACOS(0.5*(RANGE+RANGE/(X2+X1)-X2/X1-X1/X2))/CA
580  IF (BETA.EQ.0.) GO TO 6
580  IFIND=1
580  BET=CA+BETA
580  X2=X2+H2
580  ANGLE=ATAN(X2*SIN(BET)/(X2+COS(BET)-X1))/CA
580  RANGE=X2*SIN(BET)/SIN(ANGLE+CA)
580  BET=BETA
580  GO TO 8
6  RANGE=(X2/X1)+2-(SIN(ANGLE+CA))+2
6  IF (RANGE.GE.0.0) RANGE=X1+(SORT(RANGE)-ABS(COS(ANGLE+CA)))
6  IF (ANGLE.NE.0.0R.ANGLE.NE.180.)BET=ASIN(RANGE+SIN(ANGLE+CA)/X2)
6  IF (ANGLE.LT.0.) ANGLE=ANGLE+PI
6  IF (RANGE.LT.0.0) RANGE=-RANGE
6  BET=BET/CA
6  IF (WRITE.GT.1) WRITE(1,428) H1,H2,ANGLE,RANGE,BET,VIS
6  CONTINUE
6  SUMA=0.
6  IF (DELTA.GT.DAVUP.OR.DELTA.LT.DAVDN) GO TO 1500
6  V1 = 10000./DAVE2
6  V2 = 10000./DAVE1
6  DV = V2*DELTA/DAVE1
6  V1=INT(V1/5.)+5.
6  V2=(INT(V2/5.)+1)+5.
6  DV=INT(DV/5.)+5.
6  IF (DV.LT.5.)DV=5.
6  IF (XT.LE.2.AND.WRITE.GT.1) WRITE(1,403) V1,V2,DV
6  IF (ITYPE.EQ.1.AND.WRITE.GT.1) WRITE(1,407) H1,RANGE
6  IF (ITYPE.EQ.2.AND.WRITE.GT.1) WRITE(1,408) H1,H2,ANGLE
6  IF (ITYPE.EQ.3.AND.WRITE.GT.1) WRITE(1,409) H1,ANGLE
6  IF (MODEL.EQ.0) H=7
6  IF (VIS.GT.0.0.AND.WRITE.GT.1) WRITE(1,417) VIS
6  IF (VIS.LT.2.0.AND.VIS.GT.0.0.AND.WRITE.GT.1) WRITE(1,412)
6  IF (H.EQ.1.AND.WRITE.GT.1) WRITE(1,410) H
6  IF (H.EQ.2.AND.WRITE.GT.1) WRITE(1,411) H
6  IF (H.EQ.3.AND.WRITE.GT.1) WRITE(1,412) H
6  IF (H.EQ.4.AND.WRITE.GT.1) WRITE(1,413) H
6  IF (H.EQ.5.AND.WRITE.GT.1) WRITE(1,415) H
6  IF (H.EQ.6.AND.WRITE.GT.1) WRITE(1,414) H
6  IF (H.EQ.7.AND.WRITE.GT.1) WRITE(1,425)

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IF (V15,LE,0.0,AMB,INHAZE,GT,0,AMB,IURKIE,GT,1) URKIE(1,415)
INHAZE,NZ(INHAZE)
AVU=10000./V1
ALAM=10000./V2
IF (IURKIE,GT,1) URKIE(1,418) V1,V2,DV,ALAM,AVU
AVU=0.5E-4*(V1*V2)
AVU=AVU*AVU
CU=77.45+.45*AVU

CU=43.4B/.0.3973*AVU
IF (C(FIDB,EO,1) GO TO 15
IF (C(FIDB,EO,1) CALL ANGLE (H1,H2,ANGLE,BETA,LEH,RL)
IF H2=0
IF (C(F,EO,0,AMB,IURKIE,GT,1) URKIE(1,427)
IF (C(FIDB,EO,1) GO TO 15
DO 11 K=1,KMAX
VHCK)=0.0
11 CONTINUE
BETA=0.0
SR=0.0
IF=0

C**** NOW DEFINE CONSTANT PRESSURE PAIR QUANTITIES EN(1-B)
Y=CA*ANGLE
SPHI=SIN(Y)
KI=(KE+HI)*SPHI
IF (H1,GT,Z(NL)) GO TO 13
GO TO 15
X=(KE+Z(NL))/(KE+HI)
IF (SPHI,GT,X) GO TO 14
HI=Z(NL)
JI=NL
SPHI=SPHI/X
ANGLE=180.-ASIN(SPHI)/CA
KI=(KE+HI)*SPHI
GO TO 15
HAI=KI-KE
IF (IURKIE,GT,1) URKIE(1,433) HAIH
GO TO 95
DO 17 I=1,HL
F5=F(H,I)/1015.0
IS=273.15/F(H,I)
IF (H1,GT,0,AMB,H,1.7) IS=273.15/1.61,1)
X=F5*IS
F1=F5*50K(15)
B=0.1*H(H,I)
IF (H2,GT,0,AMB,H,1.7) B=0.1*H(H2,1)
EH(1,1)=B*F1*0.9
EH(2,1)=X*F1*0.75
EH(4,1)=0.78083*F1*X
FFU=4.53E-5*B*273.15/IS
EH(5,1)=B*FFU*EXP(0.08*(296.0/T(H,1)-1.0))*.002*B*(F5-F1)

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C IF SAT OPTION IS TURNED ON SO THAT UNITS IS W20
C CONTINUUM IS USED, MAKE UNITS COMATIBLE
IF (RESAT.NE.1) EN(10,1)=0*(PPU*0.12*(FS+FFU))+
+EXP(4.56*(296.07*(H,1)-1.0))
IF (NSAT.EQ.1) EN(10,1)=0*(PPU*6.12*(FS+FFU))+
+EXP(10.0483*(296.07*(H,1)-1.0))
EN(6,1)=X
HAZE=HZ1(I)
IF (H.EQ.7) HAZE=ANAZE(I)
IF (Z(I).GE.5.0) GO TO 150
IF (M.NE.7.AND.HAZE.EQ.2) HAZE=HZ2(I)
IF (HAZE.EQ.2.AND.M.EQ.7)HAZE=ANZ2(I)
IF (VIS.LE.0.0) GO TO 150
IF (M.NE.7)HAZE= 6.389*(HZ2(I)-HZ1(I))/VIS+HZ1(I)/5.0-HZ2(I)/23.0)
IF (M.NE.7) GO TO 150
HAZE=6.389*(ANZ2(I)-ANAZE(I))/VIS+ANAZE(I)/5.0-ANZ2(I)/23.0)
150 IF (HAZE.LT.0.0) HAZE=0.0
EN(7,1)=3.5336E-4*HAZE
IF (MODEL.EQ.7) EN(7,1)=HAZE/ANAZE(I)
EN(8,1)=46.6667*WU(H,1)
IF (M3.GT.0.AND.M.LT.7) EN(8,1)=46.667*WU(H3,1)
EN(3,1)=EN(8,1)*P1+0.4
IF (J)=HNO3 ABSORBER AMOUNT (ATM-CM)/CM
EN(1,1)=PS*IS*HMIX(I)+1.0E-04
EN(9,1)=1.0
REF=1.0E-6*(CD+X*1013.0/273.15-PPU*CU)
IF (1.EQ.RE) GO TO 16
IF (MODEL.EQ.0.AND.1.GE.1) GO TO 26
12-J(H,1+1)
W2=WH(H,1+1)
IF (M1.GT.0)12=1CM1,1+1)
IF (M2.GT.0)W2=WH(M2,1+1)
FFW=4.56E-4*W2+12
EN(9,1)=0.5*(REF+1.0E-6*(CD+P(H,1+1)/12-PPU*CU))
16 IF (1.EQ.RE) EN(9,1)=0.
IF (H1.GE.2(I)) J1=1
IF ((IFIND.EQ.0.0K.JP.EQ.0).AND.JURITE.GT.1) WRITE(1,434) 1,2(I),
1EN(K,1),K=1,KMAX)
EN(9,1)=EN(9,1)+1.0
17 CONTINUE
170 IF (IFIND.EQ.1) GO TO 9
IF=-1
IK=0
XI=H1
CALL POINT (H1,YH,H,WF1,IX,IP)
J1=H
IX1=IX(9)
DO 18 K=1,KMAX
18 E(K)=IX(K)
IF (ITYPE.EQ.1) GO TO 25
IF (ITYPE.EQ.3) H2=Z(H1)

```



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19 IF (CDBLE.GT.90.0) GO TO 20
   IF (CDBLE.GT.90.0.AND.NP1.GT.0) J1=J1+1
   J2=J1
   IF (TYPE.EQ.3) GO TO 20
   CALL FDIR1 (M2,Y0,R,RP,IX,IF)
   J2=J1
   IF (NP.GT.0) J2=J2+1
   DO 21 K=1,KMAX
   IF (K.EQ.9) GO TO 21
   ENCS,J1)=E(K)
   IF (TYPE.EQ.3) GO TO 21
   ENCK,J2)=E(K)
   21 CONTINUE
   IF (J1.EQ.J2) IX1=IX1YN-ENCK,J1)
C++++ NOW DEFINE VERTICAL PATH QUANTITIES VH(1-8)
   IF (JP.EQ.0.AND.IURKIE.GT.1) WRITE(1,420)
   DO 25 I=J1,J2
   X1=Z(I)
   X2=Z(I+1)
   IF (1.EQ.J1) X1=H1
   IF (1.EQ.J2) X2=H2
   DZ=X2-X1
   IF (1.EQ.HL) DZ=Z(I)-Z(I-1)
   D5=DZ
C++++ UPWARD TRAJECTORY
   RX=(RE+X1)/(RE+X2)
   THETA=ASIN(SPHI)/CA
   PHI=ASIN(SPHI+RX)/CA
   BET=THETA-PHI
   SAMP=RX*SPHI
   IF (SPHI.GT.1.E-10) D5=(RE+X2)*SIN(BET+CA)/SPHI
   BETA=BETA+BET
   PSI=BETA+PHI-ANGLE
   PHI=PHI-PHI
   SK=SK+D5
   DO 1024 K=1,KMAX
   EV=D5*ENCK,I)
   IF (1.EQ.HL) GO TO 22
   IF (ENCK,I).EQ.0.0.OR.ENCK,I+1).EQ.0.0) GO TO 23
   IF (ENCK,I).EQ.ENCK,I+1) GO TO 24
   EV=D5*(ENCK,I)-ENCK,I+1)/ALOG(ENCK,I)/ENCK,I+1)
   GO TO 24
   22 IF (ENCK,I).EQ.0.0) GO TO 23
   IF (ENCK,I-1).EQ.0.0) GO TO 23
   IF (ENCK,I).EQ.ENCK,I-1) GO TO 24
   EV=EV/ALOG(ENCK,I-1)/ENCK,I)
   GO TO 24
   23 EV=0.
   24 VICK)=VH(K)+EV
   1024 V1AY(I,K)=EV
   IF (JP.EQ.0.AND.IURKIE.GT.1) WRITE(1,435) I,X1,(VH(I),I-1),PSI,

```

1688	1689	1690	1691	1692	1693	1694	1695	1696	1697	1698	1699	1700	1701	1702	1703	1704	1705	1706	1707	1708	1709	1710	1711	1712	1713	1714	1715	1716	1717	1718	1719	1720	1721	1722	1723	1724	1725	1726	1727	1728	1729	1730	1731	1732	1733	1734	1735	1736	1737	1738	1739
1688	1689	1690	1691	1692	1693	1694	1695	1696	1697	1698	1699	1700	1701	1702	1703	1704	1705	1706	1707	1708	1709	1710	1711	1712	1713	1714	1715	1716	1717	1718	1719	1720	1721	1722	1723	1724	1725	1726	1727	1728	1729	1730	1731	1732	1733	1734	1735	1736	1737	1738	1739

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33  HMIN=60/IX3-RE
    IF (ABS(X-HMIN).GT.0.0001) GO TO 32
    IF (J1.EQ.N.AND.H2.GE.H1) YN1=IX3
    IF (J2.EQ.N.AND.J1.LE.J2) YN2=IX3
    IF (H2.GE.H1) IX2=IX3
    IF (H2.GE.H1) J2=N
    IF (H2.GE.H1.OR.H2.LT.HMIN) H=HMIN
    IF (IWRITE.GT.1) WRITE(1,436) HMIN
    IF (H2.LT.H1) J2=N
    IF (I(ITYPE.EQ.3.OR.H2.GE.H1).AND.IWRITE.GT.1) WRITE(1,437)
    ITYPE=2
    IX2=EN(9,1)
    JMIN=0
    J2=1
    H2=0.0
    H=0.0
    C**** NOW DEFINE VERTICAL PATH QUANTITIES VHC(1-8)
35  IF (JF.EQ.0.AND.IWRITE.GT.1) WRITE(1,420)
    GO 40 I=1,ML
    J=J-1
    REF=EN(9,J)
    IF (I.EQ.1) REF=YN1
    IF (I.EQ.1.AND.K2.EQ.1) REF=YN2
    IF (J.EQ.J2.AND.K2.EQ.0) REF=IX2
    IF (I.LE.1) XI=Z(J,I)
    X2=Z(J)
    IF (J.EQ.J2.AND.K2.EQ.0) X2=H
    IF (J.EQ.JMIN.AND.K2.EQ.1) X2=HMIN
    HN=(REF*XI)+SFHI-RE
    IF (HN.GT.Z(J).AND.HN.GT.X2) X2=HN
    KA=(REF*XI)/(REF*X2)
    DS=X1-X2
    ALP=90.0
    THEI=ASIN(SFHI)/CA
    SALP=KA+SFHI
    IF (ABS(X2-HN).GT.1.0E-5)ALP=ASIN(SALP)/CA
    BET=ALP-THEI
    IF (SFHI.GT.1.0E-10) DS=(KE+X2)+SIN(BET+CA)/SFHI
    THEIA=180.0-THEI
    BETA=BET+BETI
    PSI=BETA-ALP  MODLE+180.0
    SE=SE+DS
    DD 1037 K-1,KHAX
    AD=ENCK,J)
    BJ=ENCK,J+1)
    IF (J.EQ.J1) BJ=ENK)
    IF (I.EQ.J2.AND.H2.LT.H1.AND.H2.GT.0.0) A) DCE)

```



1791	IF (J1.EQ. JMIN.AND.H2.GE.H1) AJ=IX(K)	IKSIN
1792	IF (J1.EQ. JMIN.AND.ABS(H2-H1).LT.1.0E-5) AJ=IX(K)	IKSIN
1793	IF (K2.EQ.0) GO TO 34	IKSIN
1794	IF (J1.EQ. J2) BJ=B(K)	IKSIN
1795	IF (J1.EQ. JMIN) AJ=IX(K)	IKSIN
1796	IF (AJ.EQ.0.0OR.BJ.EQ.0.0) GO TO 36	IKSIN
1797	IF (AJ.EQ.0.0) GO TO 37	IKSIN
1798	IF (ABS(A1-BJ)/ABS(A1-BJ))	IKSIN
1799	GO TO 37	IKSIN
1800	IF (B5.A1)	IKSIN
1801	GO TO 39	IKSIN
1802	IF (V=0.0	IKSIN
1803	WH(K)-WH(K)+V	IKSIN
1804	IF (V.NE.0) K=V	IKSIN
1805	IF (JF.EQ.0.AND.IURITE.GT.1) WRITE(I,435) J,XI,(WH(I),I=1,9),PSI,	IKSIN
1806	beta, beta, beta, SK	IKSIN
1807	IF (J1.EQ. J2.AND.H2.GE.H1) GO TO 45	IKSIN
1808	IF (J1.EQ. JMIN.AND.K2.EQ.1) GO TO 43	IKSIN
1809	IF (J1.NE.1) KN=REF/EN(9, J-1)	IKSIN
1810	IF (J1.EQ. J2+1) KN=REF/IX2	IKSIN
1811	IF (J1.EQ. J2.AND.K2.EQ.0) KN=REF/YN2	IKSIN
1812	IF (J1.EQ. (JMIN+1).AND.K2.EQ.1) KN=REF/IX3	IKSIN
1813	IF (SALP.GE.KN) KN=1.0	IKSIN
1814	SPII=SALP*KN	IKSIN
1815	IF (J1.EQ. J2.AND.K2.EQ.0) GO TO 41	IKSIN
1816	CONTINUE	IKSIN
1817	IF (HMIN.LE.0) GO TO 47	IKSIN
1818	IF (LEH.EQ.0.AND.IURITE.GT.1) WRITE(I,436)	IKSIN
1819	IF (LEH.EQ.0) GO TO 47	IKSIN
1820	IF (LEH.EQ.1.AND.IURITE.GT.1) WRITE(I,439)	IKSIN
1821	K2=1	IKSIN
1822	XI=X2	IKSIN
1823	IF (ABS(XI-HMIN).LE.0.001) GO TO 47	IKSIN
1824	H=HMIN	IKSIN
1825	J=J2+1	IKSIN
1826	IF (CHF2.EQ.1) J=J 1	IKSIN
1827	B=beta	IKSIN
1828	H=100.-ASIN(SPIN)/CA	IKSIN
1829	IS=SK	IKSIN
1830	PS=PSI	IKSIN
1831	DO 42 K=1,KNAX	IKSIN
1832	EEK)=WH(K)	IKSIN
1833	GO TO 35	IKSIN
1834	BETA=2.0*BETA B	IKSIN
1835	PSI=2.0*PSI PS	IKSIN
1836	SK=2.0*SK IS	IKSIN
1837	TURN FATH TAKEN	IKSIN
1838	PHI=PHI	IKSIN
1839	DO 44 K=1,KNAX	IKSIN
1840	WH(K)=2.0*WH(K) ECK)	IKSIN
1841	GO TO 47	IKSIN

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45 DO 45 K=1,KMAX
46 WK(K)=2.0/WH(K)
BETA=2.0/BETA
SK=2.0/SK
IF (H2.EQ.H1) GO TO 47
KD=IXI/YHI
SFHI=SFH/DOUBLE(K)
IF (SFHI.LT.KD) SFHI=SFHI/KD
GO TO 19
47 CONTINUE
IF (IURITE.GT.1) WRITE(1,406) HM
DO 48 K=1,KMAX
WK(K)=WK(K)
48 CONTINUE
IF (IURITE.GT.1) WRITE (1,419)
IF (IURITE.GT.1) WKJE (1,1155)
IF (IURITE.GT.1) WRITE(1,421) (WC(1,1-1,8),W(10),W(11))
IF (IYPE.EQ.2.AND.H1.EQ.H2) J2=J1
IF (IYPE.EQ.1) J2=J1
IF (IURITE.GT.1) WRITE(1,1109) J1,J2
1=1
1=1
1V1=V1/5.0
1V2=V2/5.1.99
1V1=5*1V1
1V2=5*1V2
IF (1V1.LT.350) 1V1=350
IF (1V2.GT.50000) 1V2=50000
IF (DV.LT.5.) DV=5.
1V9=DV
1V=1V1-1V9
1COUNT=0
1LAW = 1
IF (1E155.EQ.0) GO TO 50
KAD50K=0.0
FACTOR=0.5
IF (IURITE.GT.1) WRITE(1,1156)
IF (IURITE.GT.1) WRITE(1,1157)
***** BEGINNING OF TRANSMITTANCE CALCULATIONS
50 1V=1V+1V9
IF (1E155.EQ.0) GO TO 1200
1LAW=0
1ADG=0
SUMV=0.
H1=H1-1
11=J1+1
1J=J1+H1
DO 1050 I=1,KMAX
E(K)=0.
1050 CONTINUE
IF (ADG.EQ.1.90.0) GO TO 1061

```

```

LEN=1.
IL=JL-1
HMR=1.0E-6
IJ=MIL
1051 CONTINUE
ILEV(IJ)=1.0
ISCA(IJ)=1.
IF (LEN.EQ.0) IL=IL+1
IF (LEN.EQ.1) IL=IL+1
IJ=IJ+1
60 1054 K=I,KMAX
DLE=E(K)*DLAY(IL,K)
1054 CONTINUE
1050 CONTINUE
IF (JF.NE.0) GO TO 52
IF (ICOUNT.EQ.0) GO TO 51
IF (ICOUNT.EQ.50) GO TO 51
GO TO 52
51 ICOUNT=0
52 IF ((HMR*.EQ.0.AND.IURITE.GT.1) WRITE(1,*)22)
    K=K+1,KMAX
    IAK=-0.0
    IF (K.LT.4) IX(K)=1.0
53 CONTINUE
    ICOUNT=ICOUNT+1
    SUM=0.0
    V=IV
    1-(IV-350)/5+1
C *****
C HMO3 ABSORPTION CALCULATION
CALL HMO3(V,HABS)
IX(11)=HABS*(11)
SUM=SUM+IX(11)
IF (IV.LT.670) GO TO 72
IF (IV.LE.3000) GO TO 61
C***** MOLECULAR SCATTERING
CS=9.867E-20*(V+.4.0117)
IX(61)=CS*(61)
SUM=SUM+IX(61)
IF (IV.LT.9200) GO TO 72
IF (IV.LT.13000) GO TO 69
C***** UV OZURE
XX=SUM
IF (IV.LE.23400) GO TO 54
IF (IV.GE.27500) GO TO 55
GO TO 67
54 XX=SUM*0
X1=(V-13000.0)/XX*1.0
11=1
12=53
GO TO 55
55 XX=SUM*0

```



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X1=(V-27500.0)/XX*57.0
11-57
12-102
56 DO 57 M=11,12
   AD=X1-FLOAT(M)
   IF (XD) 59,58,57
57 CONTINUE
58 IX(8)=D(8)+C(8)
   GO TO 60
59 IX(8)=C(8)+D(8)+C(8)-(C(8)-1)
   IX(8)=D(8)+IX(8)
60 SUM=SUM+IX(8)
   IF (IV.GT.14500) GO TO 87
   GO TO 89
C***** WATER VAPOR CONTINUUM TO NICKON REGION
61 IF (IV.GT.1350) GO TO 62
   IX(5)=(4.18+5578.0*EXP(-7.87E-3*V))+U(5)
   GO TO 66
62 IF (IV.11.2350) GO TO 68
C***** WATER VAPOR CONTINUUM A NICKON REGION
C HSAI IS SAI OPTION TO USE EITHER BUREN OR WHITE APP-1
   IF (NSAI.EQ.1) GO TO 65
   XI=(V-2350.0)/50.0+1.0
   DO 63 NH=1,15
     XI=XI-FLOAT(NH)
     IX(5)=E5(NH)
     IF (XN) 64,65,63
63 CONTINUE
64 IX(5)=IX(5)+X(NH)-C5(NH)-C5(NH-1)
65 IF (NSAI.EQ.1) IX(5)=2.0528882E-1+8.6530478E-6+
   (V-2599.3)+2
   IX(5)=IX(5)+U(10)
66 SUM=SUM+IX(5)
   IF (IV.1E.1350.0R.1V.GT.2740) GO TO 72
C***** RIKOGEW CONTINUUM
68 IF (IV.11.2080) GO TO 72
   K4=1-346
   IX(4)=C4(K4)+U(4)
   SUM=SUM+IX(4)
   GO TO 72
C***** WATER VAPOR
69 IF (IV.11.1200.60R.1V.6E.9875) GO TO 70
   IF (IV.1E.1420.60R.1V.6E.13400) GO TO 71
   GO TO 76
70 I=1-155
   GO TO 72
71 I=1-255
72 I=1
   IF (U(1.11.1.6E-20) GO TO 76
   OSI=OSI+U(1.11.1.6E-20)

```

IR510 1944  
IR510 1945  
IR510 1946  
IR510 1947  
IR510 1948  
IR510 1949  
IR510 1950  
IR510 1951  
IR510 1952  
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IR510 1954  
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IR510 1988  
IR510 1989  
IR510 1990  
IR510 1991  
IR510 1992  
IR510 1993

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```
73 IF (US1.L1.-2.3468) IX(1)=1.-.087787*EXP(1.055595*US1)
74 IF (US1.L1.-2.3468) GO TO 74
75 IF (US1.G1.3.5682) GO TO 75
76 IF (US1.G1.2.0) K1=40
77 GO 73 K=K1,67
78 IF (US1.L1.FU(K)) GO TO 74
79 CONTINUE
80 IX(1)=IR(K)+(IR(K)-1)-IR(K))*(FU(K)-US1)/(FU(K)-FUCK-1))
81 GO TO 74
82 IX(1)=0.0
83 CONTINUE
84 C***** UNIFORMLY MIXED GASES
85 IF (IV.L1.8060.AND.IV.6E.500) GO TO 77
86 IF (IV.L1.13190.AND.IV.6E.12970) GO TO 78
87 GO TO 83
88 1-1-30
89 GO TO 79
90 J=(IV-12950)/51516
91 IF (J.L1.1.1.0E-20) GO TO 83
92 K1=1
93 US2=31.061010(2)+C2(J)
94 IF (US2.L1.-2.3468) IX(2)=1.-.087787*EXP(1.055595*US2)
95 IF (US2.L1.-2.3468) GO TO 83
96 IF (US2.G1.3.5682) GO TO 82
97 IF (US2.G1.2.0) K1=40
98 GO 80 K=K1,67
99 IF (US2.L1.FU(K)) GO TO 81
100 CONTINUE
101 IX(2)=IR(K)+(IR(K)-1)-IR(K))*(FU(K)-US2)/(FU(K)-FUCK-1))
102 GO TO 83
103 IX(2)=0.0
104 CONTINUE
105 C***** OZONE
106 IF (IV.L1.5.25.0E.10.6E.12270) GO TO 87
107 1-1-45
108 K1=1
109 IF (IV.L1.1.1.0E-20) GO TO 87
110 US3=31.061010(3)+C3(J)
111 IF (US3.L1.-1.6778) IX(3)=1.-.055194*EXP(2.367853*US3)
112 IF (US3.L1.-1.6778) GO TO 87
113 IF (US3.G1.3.9345) GO TO 86
114 IF (US3.G1.1.5) K1=36
115 GO 84 K=K1,67
116 IF (US3.L1.FU(K)) GO TO 85
117 CONTINUE
118 IX(3)=IR(K)+(IR(K)-1)-IR(K))*(FU(K)-US3)/(FU(K)-FUCK-1))
119 GO TO 87
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05 IX(3)=0.0
07 CONTINUE
C***** AEROSOL EXTINCTION
ALAN=1.0E+4/V
XX=0.0
YY=0.0
IF (THAZE.EQ.0.0) GO TO 90
DO 88 N=1,44
XD=ALAN-VX(N)
IF (XD)89,88,88
03 CONTINUE
09 XX=(CZ(N)-CZ(H-1))+XB/(VX(N)-VX(H-1))+CZ(H)
YY=(CZ(A(N)-CZ(A(H-1))+XD/(VX(H)-VX(H-1))+CZ(A(H))
90 IX(10)=YY+Q(7)
IX(7)=XX+Q(7)
SUM=SUM+IX(7)
IX(9)=SUM
DO 94 K=4,KMAX
IF (IX(K).EQ.0.0) GO TO 92
IF (IX(K).LE.0.1) GO TO 91
IF (IX(K).GT.20.) GO TO 93
IX(K)=EXP(-IX(K))
GO TO 94
91 IX(K)=1.0-IX(K)+0.5*IX(K)+IX(K)
GO TO 94
92 IX(K)=1.0
GO TO 94
93 IX(K)=0.
94 CONTINUE
IX(9)=IX(1)+IX(2)+IX(3)+IX(9)
IF (IV.6E-13000) IX(3)=IX(8)
IF (LENISS.EQ.0) GO TO 1210
ALAN=1.0E+04/V
IFAK=(C(H,IL)+C(H,IL+1))/0.5
BB(IJ)=FF(I)B(K,9)
ILEV(IJ)=(IX(1)+IX(9)+IX(10))/(IX(7)+IX(5))
ISCAT(IJ)=(IX(7)+IX(5))/IX(10)
B(50)=ILEV(IJ)-ILEV(IJ)
IF (I)AD.1.1.E-5.AND.ILEV(IJ).LT.1.0E-5) GO TO 1104
SUMV=SUMV+0.5*B(IJ)*OTAB*(ISCAT(IJ)+ISCAT(IJ))
IF (IL.EQ.3.AND.UNIN.LE.0.0) TAB6=IX(9)
GO TO 1103 K=I,KMAX
IX(K)=B(K)
1103 CONTINUE
C
IF (ANGLE.LE.90.0.AND.IL.EQ.33) GO TO 1104
IF (ANGLE.LE.90.0.AND.IL.EQ.NLL) GO TO 1104
IF (ITYPE.EQ.1) GO TO 1104
IF (ITYPE.EQ.3.AND.ANGLE.LE.90.0) GO TO 1062
IF (ITYPE.EQ.3.AND.LEN.EQ.1.AND.IL.EQ.J2) GO TO 1104
IF (ITYPE.EQ.2.AND.LENSTO.EQ.0.AND.IL.EQ.J2) GO TO 1104
IF (IL.EQ.UNIN.AND.UNIN.GT.0) LEN=1

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IF (IL.EQ.1.AND.HMIN.LE.0.0) GO TO 1104
IF (IER.EQ.0) GO TO 1062
IF (IL.EQ.HMIN.AND.IJ.EQ.IL+MLL) IL=IL-1
IF (IIFYE.EQ.2.AND.IL.EQ.I2) GO TO 1104
GO TO 1062
1104 CONTINUE
JJ=J(M,1)
BKG=FF(11,V),TAUG
IF (HMIN.LE.0) SUNV=SUNV+BKG
SUNV=SUNV
IF (IV.GT.IV1) FACTOR=1.0
IF (IV.GE.IV2) FACTOR=0.5
SUNV=(1.0E+04/V**2)+SUNV
KADSUM=KADSUM+DV*FACTOR+SUNV
IF (IWRITE.GT.1) WRITE(1,1160) V,ALAM,SUNV,SUNVV,KADSUM,IX(9)
KAFK=LA-KDUM
KDUM=KDUM+1
AFK(KAFK)=SUNV
TAUA(KAFK)=IX(9)
90/5 FUKA(I(X15,2E12,3))
IF (IWRITE.GT.1) WRITE(1,1160) V,ALAM,SUNV,SUNVV,KADSUM,IX(9)
I210 IX(10)=1-IX(10)
AB=1-IX(9)
IF (IV.EQ.IV1.OR.IV.EQ.IV2) AB=0.5+AB
SUNV=SUNV+AB*DV
IF (IEMISS.EQ.1) GO TO 1220
IF (JF.EQ.0.AND.IWRITE.GT.1) WRITE(1,423) IV,ALAM,IX(9),(TX(9),
IK-1,3),IX(10),SUNA
UNAVE(11AM) = ALAM
TOTAL(11AM) = IX(9)
11AM = 11AM + 1
1105 CONTINUE
IF (IV.GE.IV2) GO TO 95
GO TO 50
1106 CONTINUE
AB=1.0 SUNV(IV2-V1)
IF (IWRITE.GT.1) WRITE(1,424) IV1,IV2,SUNV,AB
KAD(3,1107)IXY
IF (IWRITE.GT.1) WRITE(1,400) IXY
IF (IX.EQ.0) GO TO 100
GO TO (95,2,97,98,100),IXY
1107 CONTINUE
1108 CONTINUE
GO TO 405, 91,92,90
1109 CONTINUE
1110 CONTINUE
1111 CONTINUE
1112 CONTINUE
1113 CONTINUE
1114 CONTINUE
1115 CONTINUE
1116 CONTINUE
1117 CONTINUE
1118 CONTINUE
1119 CONTINUE
1120 CONTINUE
1121 CONTINUE
1122 CONTINUE
1123 CONTINUE
1124 CONTINUE
1125 CONTINUE
1126 CONTINUE
1127 CONTINUE
1128 CONTINUE
1129 CONTINUE
1130 CONTINUE
1131 CONTINUE
1132 CONTINUE
1133 CONTINUE
1134 CONTINUE
1135 CONTINUE
1136 CONTINUE
1137 CONTINUE
1138 CONTINUE
1139 CONTINUE
1140 CONTINUE
1141 CONTINUE
1142 CONTINUE
1143 CONTINUE

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900 CONTINUE
IF (CMISS.EQ.1.AND.IWRITE.GT.1) WRITE(1,1170)
IF (CMISS.EQ.0.AND.IWRITE.GT.1) WRITE(1,1171)
LENSTO = LEN
IF (IWRITE.GT.1) WRITE(1,400)MODEL,IMAZE,ITYPE,ICW,JP,Id,dt,
IM2,M3,M4,CMISS,K0
GO TO 200

100 ILM = 1
XUAVE(1) = WAVE(1)
KIAM = 1

1978 IF (XUAVE(KIAM)-LT.WAVE(ILAM+1)) ILM=ILAM + 1
TOTRAN(KIAM) = TOTAL(ILAM) + (XUAVE(KIAM) - WAVE(ILAM)) +
(WAVE(ILAM+1)-(TOTAL(ILAM+1)-TOTAL(ILAM)))/(WAVE(ILAM+1)-
WAVE(ILAM))/XUAVE(KIAM)
IF (KIAM.GE.LW) GO TO 2000
XUAVE(KIAM+1)=WAVE(1)-DELAM+KIAM
KIAM = KIAM + 1
GO TO 1978

2000 CONTINUE
LW=LW
DO 1988 I=1,LW
TOTRAN(I)=TOTRAN(LW)
LW=LW-1

1988 CONTINUE
DO 1999 I=1,LW
TOTRAN(I)=TOTRAN(1)

1999 CONTINUE
ISF = 1
RETURN

1500 IF (IWRITE.GT.1) WRITE(1,450)
STOP

400 FORMAT(1113,F10.3)
1170 FORMAT(1) PROGRAM WILL BE EXECUTED IN THE EMISSION MODE*
1171 FORMAT(1) PROGRAM WILL BE EXECUTED IN THE TRANSMISSION MODE*
401 FORMAT (B610.3)
402 FORMAT (F5.1,2(E10.3,F6.1,2E10.3))
403 FORMAT (4(F6.3,2F7.4))
404 FORMAT (15F5.2)
405 FORMAT (B9.2)
406 FORMAT (7F10.3)
407 FORMAT (//10X,28H HORIZONTAL PATH, ALTITUDE =,F7.3,11H KM,RANGE =,
F7.3,3H KM)
408 FORMAT (//10X,50H SLANT PATH BETWEEN ALTITUDES H1 AND H2 WHERE H1
=,F7.3,8H KM H2 =,F7.3,18H KM,ZENITH ANGLE =,F7.3,8H DEGREES)
409 FORMAT (//10X,39H SLANT PATH TO SPACE FROM ALTITUDE H1 =,F7.3,19H
KM,ZENITH ANGLE =,F7.3,8H DEGREES)
410 FORMAT (//20X,18H MODEL ATMOSPHERE ,11,11H = TROPICAL)
411 FORMAT (//20X,18H MODEL ATMOSPHERE ,11,21H = MIDLATITUDE SUMMER)
412 FORMAT (//20X,18H MODEL ATMOSPHERE ,11,21H = MIDLATITUDE WINTER)
413 FORMAT (//20X,18H MODEL ATMOSPHERE ,11,21H = SUB-ARCTIC SUMMER)
414 FORMAT (//20X,18H MODEL ATMOSPHERE ,11,21H = 1962 US STANDARD)

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415 FURNAT (/20X,10H MODEL ATMOSPHERE ,11,21H = SUB-ARCTIC WINTER ) IRSTH 2195  
416 FURNAT (/20X,10H HAZE MODEL ,11,3H = ,A5,13H VISUAL RANGE) IRSTH 2196  
417 FURNAT (/25X+HAZE MODEL =,FS,1, + KM VISUAL RANGE AT SEA LEVEL+) IRSTH 2197  
418 FURNAT (/10X,21H FREQUENCY RANGE VI= ,F7.1,13H CM-1 TO V2= ,F7.1,1 IRSTH 2198  
419 FURNAT (/10X,21H FREQUENCY RANGE VI= ,F7.1,13H CM-1 TO V2= ,F7.1,1 IRSTH 2199  
420 FURNAT (/10X,30H EQUILIVANT SEA LEVEL ABSORBER AMOUNTS/21X110HNAI IRSTH 2200  
421 FURNAT (/10X,30H EQUILIVANT SEA LEVEL ABSORBER AMOUNTS/21X110HNAI IRSTH 2201  
422 FURNAT (/10X,30H EQUILIVANT SEA LEVEL ABSORBER AMOUNTS/21X110HNAI IRSTH 2202  
423 FURNAT (/10X,30H EQUILIVANT SEA LEVEL ABSORBER AMOUNTS/21X110HNAI IRSTH 2203  
424 FURNAT (/10X,30H EQUILIVANT SEA LEVEL ABSORBER AMOUNTS/21X110HNAI IRSTH 2204  
425 FURNAT (/10X,30H EQUILIVANT SEA LEVEL ABSORBER AMOUNTS/21X110HNAI IRSTH 2205  
426 FURNAT (/10X,30H EQUILIVANT SEA LEVEL ABSORBER AMOUNTS/21X110HNAI IRSTH 2206  
427 FURNAT (/10X,30H EQUILIVANT SEA LEVEL ABSORBER AMOUNTS/21X110HNAI IRSTH 2207  
428 FURNAT (/10X,30H EQUILIVANT SEA LEVEL ABSORBER AMOUNTS/21X110HNAI IRSTH 2208  
429 FURNAT (/10X,30H EQUILIVANT SEA LEVEL ABSORBER AMOUNTS/21X110HNAI IRSTH 2209  
430 FURNAT (/10X,30H EQUILIVANT SEA LEVEL ABSORBER AMOUNTS/21X110HNAI IRSTH 2210  
431 FURNAT (/10X,30H EQUILIVANT SEA LEVEL ABSORBER AMOUNTS/21X110HNAI IRSTH 2211  
432 FURNAT (/10X,30H EQUILIVANT SEA LEVEL ABSORBER AMOUNTS/21X110HNAI IRSTH 2212  
433 FURNAT (/10X,30H EQUILIVANT SEA LEVEL ABSORBER AMOUNTS/21X110HNAI IRSTH 2213  
434 FURNAT (/10X,30H EQUILIVANT SEA LEVEL ABSORBER AMOUNTS/21X110HNAI IRSTH 2214  
435 FURNAT (/10X,30H EQUILIVANT SEA LEVEL ABSORBER AMOUNTS/21X110HNAI IRSTH 2215  
436 FURNAT (/10X,30H EQUILIVANT SEA LEVEL ABSORBER AMOUNTS/21X110HNAI IRSTH 2216  
437 FURNAT (/10X,30H EQUILIVANT SEA LEVEL ABSORBER AMOUNTS/21X110HNAI IRSTH 2217  
438 FURNAT (/10X,30H EQUILIVANT SEA LEVEL ABSORBER AMOUNTS/21X110HNAI IRSTH 2218  
439 FURNAT (/10X,30H EQUILIVANT SEA LEVEL ABSORBER AMOUNTS/21X110HNAI IRSTH 2219  
440 FURNAT (/10X,30H EQUILIVANT SEA LEVEL ABSORBER AMOUNTS/21X110HNAI IRSTH 2220  
441 FURNAT (/10X,30H EQUILIVANT SEA LEVEL ABSORBER AMOUNTS/21X110HNAI IRSTH 2221  
442 FURNAT (/10X,30H EQUILIVANT SEA LEVEL ABSORBER AMOUNTS/21X110HNAI IRSTH 2222  
443 FURNAT (/10X,30H EQUILIVANT SEA LEVEL ABSORBER AMOUNTS/21X110HNAI IRSTH 2223  
444 FURNAT (/10X,30H EQUILIVANT SEA LEVEL ABSORBER AMOUNTS/21X110HNAI IRSTH 2224  
445 FURNAT (/10X,30H EQUILIVANT SEA LEVEL ABSORBER AMOUNTS/21X110HNAI IRSTH 2225  
446 FURNAT (/10X,30H EQUILIVANT SEA LEVEL ABSORBER AMOUNTS/21X110HNAI IRSTH 2226  
447 FURNAT (/10X,30H EQUILIVANT SEA LEVEL ABSORBER AMOUNTS/21X110HNAI IRSTH 2227  
448 FURNAT (/10X,30H EQUILIVANT SEA LEVEL ABSORBER AMOUNTS/21X110HNAI IRSTH 2228  
449 FURNAT (/10X,30H EQUILIVANT SEA LEVEL ABSORBER AMOUNTS/21X110HNAI IRSTH 2229  
450 FURNAT (/10X,30H EQUILIVANT SEA LEVEL ABSORBER AMOUNTS/21X110HNAI IRSTH 2230  
451 FURNAT (/10X,30H EQUILIVANT SEA LEVEL ABSORBER AMOUNTS/21X110HNAI IRSTH 2231  
452 FURNAT (/10X,30H EQUILIVANT SEA LEVEL ABSORBER AMOUNTS/21X110HNAI IRSTH 2232  
453 FURNAT (/10X,30H EQUILIVANT SEA LEVEL ABSORBER AMOUNTS/21X110HNAI IRSTH 2233  
454 FURNAT (/10X,30H EQUILIVANT SEA LEVEL ABSORBER AMOUNTS/21X110HNAI IRSTH 2234  
455 FURNAT (/10X,30H EQUILIVANT SEA LEVEL ABSORBER AMOUNTS/21X110HNAI IRSTH 2235  
456 FURNAT (/10X,30H EQUILIVANT SEA LEVEL ABSORBER AMOUNTS/21X110HNAI IRSTH 2236  
457 FURNAT (/10X,30H EQUILIVANT SEA LEVEL ABSORBER AMOUNTS/21X110HNAI IRSTH 2237  
458 FURNAT (/10X,30H EQUILIVANT SEA LEVEL ABSORBER AMOUNTS/21X110HNAI IRSTH 2238  
459 FURNAT (/10X,30H EQUILIVANT SEA LEVEL ABSORBER AMOUNTS/21X110HNAI IRSTH 2239  
460 FURNAT (/10X,30H EQUILIVANT SEA LEVEL ABSORBER AMOUNTS/21X110HNAI IRSTH 2240  
461 FURNAT (/10X,30H EQUILIVANT SEA LEVEL ABSORBER AMOUNTS/21X110HNAI IRSTH 2241  
462 FURNAT (/10X,30H EQUILIVANT SEA LEVEL ABSORBER AMOUNTS/21X110HNAI IRSTH 2242  
463 FURNAT (/10X,30H EQUILIVANT SEA LEVEL ABSORBER AMOUNTS/21X110HNAI IRSTH 2243  
464 FURNAT (/10X,30H EQUILIVANT SEA LEVEL ABSORBER AMOUNTS/21X110HNAI IRSTH 2244  
465 FURNAT (/10X,30H EQUILIVANT SEA LEVEL ABSORBER AMOUNTS/21X110HNAI IRSTH 2245



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1155 FORMAT (11X, 'INTEGRAL')
1156 FORMAT (11X, 'RADIANCE (MILLIWATTS/CM2-STER-RADIANT)')
1157 FORMAT (30X, 'FK(CM-1) UVL(MICRON) PER CM-1 PER MICRON, '
1 INTEGRAL
      IRADS)
1160 FORMAT(30X, 'U.1, U.13.0, U.13.5, F13.6)
      END
SUBROUTINE HRO3 (V, HABS)
  DIMENSION H(15), H2(15), H3(15)
  C ARRAY H1 CONTAINS HRO3 ABS, COEF(CM-IATM-1) FROM 0.50 TO 2.0 CM-1
  DATA H1/2.197, 3.711, 5.154, 8.150, 9.217, 9.481, 11.55, 11.10, 11.17, 12.4
    10, 10.49, 7.509, 6.136, 4.099, 2.865/
  C ARRAY H2 CONTAINS HRO3 ABS, COEF(CM-IATM-1) FROM 12.75 TO 101.50 CM-1
  DATA H2/2.020, 4.411, 6.755, 8.759, 10.51, 13.74, 18.00, 21.51, 23.09, 21.6
    18, 21.32, 16.02, 16.42, 17.87, 14.06, 8.716/
  C ARRAY H3 CONTAINS HRO3 ABS, COEF(CM-IATM-1) FROM 12.75 TO 101.75 CM-1
  DATA H3/5.003, 0.003, 14.12, 19.83, 23.31, 23.58, 21.22, 21.09, 26.99, 25.8
    14, 24.79, 17.68, 9.420/
  HABS=0.
  IF (V.LE.0.50.AND.V.LE.920.0) GO TO 1000
  IF (V.LE.1275.0.AND.V.LE.1350.0) GO TO 1001
  IF (V.LE.1675.0.AND.V.LE.1735.0) GO TO 1002
  GO TO 1003
1000 I=(V-845.)/5.
  HABS=H1(I)
  GO TO 1003
1001 I=(V-1270.)/5.
  HABS=H2(I)
  GO TO 1003
1002 I=(V-1670.)/5.
  HABS=H3(I)
1003 RETURN
      END
SUBROUTINE POINT (X, YN, M, HP, TX, TP)
  COMMON Z(34), F(7, 34), T(7, 34), EH(11, 34), WH(7, 34), M, HL, RE, CU, CO, FI
  COMMON KMAX
  DIMENSION TX(11)
  C *****
  C SUBROUTINE POINT COMPUTES THE MEAN REFRACTIVE INDEX ABOVE AND BELOW
  C A GIVEN ALTITUDE AND INTERPOLATES EXTERNALLY TO DETERMINE THE
  C EQUIVALENT ABSORBER AMOUNTS AT THAT ALTITUDE.
  C *****
  C X IS THE HEIGHT IN QUESTION
  C TX(9) AND YN ARE THE MEAN REFRACTIVE INDICES ABOVE AND BELOW X
  C H IS THE LEVEL INTEGER CORRESPONDING TO X OR THE LEVEL BELOW X
  C HP = 1 IF X COINCIDES WITH MODEL ATMOSPHERE LEVEL, IF NOT HP = 0
  C TX(1-8) ARE ABSORBER AMOUNTS PER CM AT HEIGHT X
  C *****
  IF

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MP=0
IF (X.LI-0.0) X=0.
IF (X.GT.2(M)) GO TO 4
DO 1 I=1,M
  N=I
  IF (X-Z(I)) 2,4,1
  CONTINUE
  J2=N
  N=N-1
  FAC=(X-Z(N))/(Z(J2)-Z(N))
  FX1=F(N,N)+(F(N,J2)/P(N,N))*FAC
  TX1=T(N,N)+(T(N,J2)/T(N,N))*FAC
  UX1=UH(N,N)+(UH(N,J2)/UH(N,N))*FAC
  TX(3)=CO*FX1/TX1-4.56E-6*UX1+TX1*CU
  TX(2)=CO*P(N,J2)/T(N,J2)-4.56E-6*UH(N,J2)+T(N,J2)*CU
  TX(1)=CO*P(N,N)/T(N,N)-4.56E-6*UH(N,N)+T(N,N)*CU
  TX(9)=0.5E-6*(TX(2)+TX(3))
  YH=0.5E-5*(TX(1)+TX(3))
  IF (CIP.EQ.0) GO TO 9
  DO 3 K=1,KHAX
    IF (K.EQ.9) GO TO 3
    TX(K)=0.0
    IF (EH(K,N).EQ.0.0) GO TO 3
    IF (EH(K,N).GT.1000.0) GO TO 3
    TX(K)=EH(K,N)*(EH(K,J2)/EH(K,N))*FAC
  CONTINUE
  GO TO 9
MP=1
IF (CIP.EQ.0) GO TO 6
DO 5 K=1,KHAX
  TX(K)=EH(K,N)
  TX(9)=EH(9,N)-1.
YH=0.0
C***** LINES B 24 AND 50 THROUGH 59 ARE NO LONGER REQUIRED
IF (H.GT.1) YH=EH(9,N-1)-1.0
CONTINUE
IF (CIP.EQ.1) PRINT 400, X,N,MP,IX(9),YH,IP,(TX(K),K=1,9)
TX(9)=TX(9)+1.
YH=YH+1.
RETURN
C
400  FORMAT (/,+ FROM POINT- HEIGHT=+,F10.4,+ KM,N=+,I3,+ MP=+,I2,+ REF
      1. INDEX ABOVE + BELOW X=+,2E11.4,+ IF=+,I3,+ /,I2X, +EQUID. ORDER
      2.AMOUNTS PER KM AT X=+,BE10.3)
      END
SUBROUTINE ANGL (H1,H2,ANGLE,B1,LEN,M1)
COMMON Z(34),P(7,34),T(7,34),EH(11,34),UH(7,34),M,M1,KE,CU,CU,P1
COMMON KHAX
DIMENSION IX(11)
C*****
C

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C THIS SUBROUTINE CALCULATES THE INITIAL ZEROTH ORDER CORRECT
C TAKING INTO ACCOUNT REFRACTION EFFECTS GIVEN H1,H2, AND BETA
C (WHERE BETA IS THE EARTH CENTRE ANGLE SUBTENDED BY H1 AND H2 ),
C ASSUMING THE REFRACTIVE INDEX TO BE CONSTANT IN A GIVEN LAYER.
C FOR GREATER ACCURACY INCREASE THE NUMBER OF LEVELS IN THE MODEL
C ATMOSPHERE.
C
C THIS SUBROUTINE CAN BE REMOVED FROM THE PROGRAM IF NOT REQUIRED.
C*****
      IF-99
      CA=PI/180.
      X1=RE+H1
      X2=RE+H2
      LEN=0.
      IF=0
      B1=B1+CA
      IF(B1.EQ.0.0)B1=ACOS(X2/X1)
      TANG=X2*SIN(B1)/(X2+COS(B1)-X1)
      THET=ATAN(TANG)
      IF (THET.LT.0.0) THET=THET+PI
      SFH1=SIN(THET)
      ANG=THET/CA
      PRINT 404, B1,ANG,TANG
      TH=THET
      TH=TH-0.5*CA
      ANGLE=THET
      F01=0.
      BETA=0.
      BETA=0
      BETA=0
      F01=0
      F02=0
      F03=0.0
      IF(B1.EQ.0.0) GO TO 2
      PRINT 400, IF
      F01=THET
      IF (F1.GT.1.0E-0) GO TO 9
      IF (F1.EQ.100) GO TO 6
      X01=X2+COS(B1)-RE
      IF (X01-B1) B,4,4
      2 H01=H2
      H2=H1
      H1=H01
      ANGLE=0.5*PI
      THET=ANGLE
      SFH1=1.0
      ANG=ANGLE/CA
      PRINT 404, B1,ANG,SFH1
      IF=100
      CALL FOURTH (H1,H2,B,RP,IX,IF)
      IF=0

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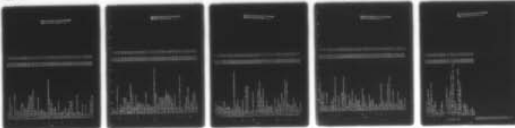
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INFRARED SEARCH AND TRACK EVALUATION MODEL (IRSTEM).(U)  
AUG 78 L N PECKHAM, L L DORAN  
SAI-A64-995-199

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5  (A1=IACV)
   CALL POINT (H2,YH,H,MP,IX,IP)
   IF (MP.EQ.1) H=H-1
   J2=H
   IF (J1.EQ.J2) TX1=IX1*YH*EH(9,J1)
   DO 7 J=J1,J2
     XI=KEZ(J)
     X2=KEZ(J+1)
     IF (J1.EQ.J1) XI=KEH1
     IF (J1.EQ.J2) X2=KEH2
     SALP=X1*SFH1/X2
     ALP=ASIN(SALP)
     RM=EH(9,J1)/EH(9,J)
     IF (J1).EQ.J2) RM=YH/EH(9,J)
     IF (J1.EQ.J1) RM=EH(9,J1)/TX1
     IF (J1).EQ.J2.AND.J.EQ.J1) RM=YH/TX1
     BET=THE1-ALP
     FB=-IAR(ALP)
     IF (J.NE.J1) FB=FB+IAR(THET)
     FBT=FBT+FB
     BETA=BETA+BET
     TH1=THE1/CA
     BE=BET/CA
     C=ALP/CA
   PRINT 402, J,Z(J),THET,ALP,BET,BETA,FBT,FB,TH1,BE,C
   IF (X2.EQ.KEH2) C=PI-ALP
   IF (SALP.GE.KN) KN=1.
   SPH1=SALP/RM
   THE1=ASIN(SPH1)
   CONTINUE
   IF(B1.LE.0.0) GO TO 29
   GO TO 26
   CONTINUE
   IANG=-IANG
   ANGLE=PI-ANGLE
   TH=ANGLE
   ANG=ANGLE/CA
   PRINT 404, B1,ANG,IANG
   IF (M1.LE.0.0) GO TO 3
   CONTINUE
   IF=101
   CALL POINT (M1,YH,M,MP1,IX,IP)
   TX1=TX(9)
   YH1=YH
   IF (MP1.EQ.1) M=M-1
   J2=M
   IF (M.EQ.7) J2=M1
   J1=M
   J=J1+1
   IF (H2.GE.H1) GO TO 13
   CALL POINT (H2,YH,H,MP,IX,IP)

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```

10  X2=IX(Y)
    YN2=YN
    J2=M
    IF (J1.EQ.J2) X2=YMI+IX(9)-EN(9,J1)
    J=J-1
    X1=KE+Z(J+1)
    X2=KE+Z(J)
    IF (J.EQ.J1) X1=KE+M1
    IF (J.EQ.J2) X2=KE+M2
    SALP=X1+SPMI/X2
    MNIM=X1+SPMI-KE
    PRINT 402, J,X1,Z(J),SPMI,SALP,MNIM,KE
    IF (SALP.LE.1.0) GO TO 11
    SALP=SPMI
    IF (MNIM.GT.M2) GO TO 10
    ALP=ASIM(SALP)
    THET=ASIM(SPMI)
    BET=ALP-THET
    BET1=BET1+BET
    FB=TAM(ALP)
    IF (J.NE.J1) FB=FB-TAM(THET)
    FB11=FB11+FB
    TM1=THET/CA
    BE=BET/CA
    AL=ALP/CA
    PRINT 402, J,X2,THET,ALP,BET1,BET,MNIM,MNIM,FB11,TH1,BE,AL
    IF (X2.EQ.KE+M2) C=PI-ALP
    KE=EN(9,J)
    IF (J.EQ.J1) KE=YMI
    IF (J.EQ.J2) KE=IX2
    IF (J.EQ.1) GO TO 12
    KM=EN(9,J)/EN(9,J-1)
    IF (J.EQ.J1) KM=YMI/EN(9,J-1)
    IF (J.EQ.J2+1) KM=KE/IX2
    IF (J.EQ.J2) KM=KE/YN2
    IF (SALP.GE.KM) KM=1.
    SPMI=SALP/KM
    IF (Z(J).LE.M2) GO TO 12
    GO TO 10
12  X1=X2
    IF (ABS(Z(J)-M2).LT.1.0E-10.AND.J.ME.1) GO TO 13
    GO TO 14
13  J=J-1
    X1=KE+Z(J+1)
    IF (J.EQ.J1) X1=KE+M1
    IF (J.EQ.J2.AND.J.ME.J1) X1=KE+M2
    X2=KE+Z(J)
    MNIM=X1+SPMI-KE
    IF (MNIM.LE.0.0) GO TO 25
    IF (Z(J).LT.MNIM) GO TO 10
    KE=EN(9,J)

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11 (J.EQ.J2) HET=H
   ALP=XI*SPHI/X2
   THE1=ASIN(SPHI)
   ALP=ASIN(SALP)
   REF=ALP-THE1
   FB=IAR(ALP)-IAR(THE1)
   FB2=FB2+FB
   BET2=BET2+BET
   HMIN=BET1+BET2
   AL=ALP/CA
   THE1=THE1/CA
   PRINT 402, J,X2,THE1,ALP,BET2,BET,HMIN,HMIN,FB2,THE1,BE,AL
   EN=REF/EN(9,J-1)
   IF (SALP.GE.EN) EN=1.0
   SPHI=SALP*EN
   GO TO 13
17 TX3=THE1*TX(9)-EN(9,J1)
   THE1=TX3
   IF (ABS(H2-Z(J,1)).LE.1.0E-5) THE1=TX(9)
   IF (ABS(SIN-Z(J,1)).LE.1.0E-5) THE1=TX(9)
   EN=1.0
   GO TO 19
18 CALL POINT (HMIN,THE1,M,WP,TX,IP)
   IF=102
   TX3=TX(9)
   IF (J.EQ.J1.AND.N2.GE.H1) GO TO 17
   IF (J.EQ.J1.OR.J.EQ.J2) TX3=THE1*TX(9)-EN(9,J)
   IF (HMIN.GT.N2) TX3=TX(9)
   IF (J.EQ.J1.AND.HMIN.GT.N2) GO TO 17
   FB=REF/TX3
   IF (SALP.GE.EN) EN=1.
   SPHI=SALP*EN
   X=XI*SPHI-KE
   BIF=ABS(HMIN-X)
   HMIN=X
   IF (BIF-1.0E-5) 19,19,18
19 X2=KE*HMIN
   PRINT 403, HMIN,BIF,EN
   THE1=ASIN(SPHI)
   IF (EN.EQ.1.0) FB2=-IAR(THE1)
   IF (EN.EQ.1) GO TO 20
   BHA=(TX3-1.0)*ALOG((TX3-1.0)/(REF-1.0))/(X2-X1)
   FB2=-IAR(THE1)+1.0-1.0/(1.0+TX3/(X2*BHA))
   BET2=BET1-THE1
   BET2=BET2+BET
   HMIN=BET1+BET2
   IF (H2.GE.H1) GO TO 23
   BET=BET12+BET2
   BET=BET1-BET1
   BET2=BET1-B1
   IF3=ABS(BHA-B1)

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22 IF (DB2.GI.DBI.DD0.DD2.GI.DD1) GO TO 25
   IF (DB2.GI.DD3) GO TO 22
   IF (DB2.GI.DD1) GO TO 25
   BETA=BEI
   FBI=FBI1+2.0*(FBI2+FBI3)
   LEM=1.
   GO TO 24
22 BETA=BEI+BEI2
   FBI=FBI1+FBI2+FBI3
   C PRINT 401, J,BETA,FBI,FBI1,FBI2,FBI3,IXI,YMI
   GO TO 26
23 BETA=2.0*(BEI+BEI2)
   LEM=1.
   FBI=2.0*(FBI1+FBI2+FBI3)
   PRINT 401, J,BETA,FBI,FBI1,FBI2,FBI3,IXI,YMI
   IF (M2.EQ.M1) GO TO 26
   IF=103
   IF (MFI.EQ.1) J1=J1+1
   SPHI=SIN(ANGLE)
   IF (X(J1+1).LE.N2) GO TO 24
   KM=IXI/YMI
   IF (SPHI.GE.KM) KM=1.
   SPHI=SPHI/KM
   THET=ASIN(SPHI)
   GO TO 5
24 CALL POINT (M2,YM,M,MP,IX,IF)
   IXI=IXI+YM-EN(9,J1)
   KM=IXI/YMI
   J2=J1
   IF (SPHI.GE.KM) KM=1.
   SPHI=SPHI/KM
   THET=ASIN(SPHI)
   GO TO 5
25 BETA=BEI
   LEM=0.
   FBI=FBI1
   THET=ANGLE*(B1-BETA)/(1.9FBI/TANG)
   BETA=BETA/CA
   B=BEI/CA
   TH1=THET/CA
   PRINT 404, BETA,BETA,FBI,TH1,TANG
   IF (THET.GT.PI*.6K.THET.LT.PI) THET=(THET+PI)/2.
   TH1=THET/CA
   PRINT 404, BEI,B,FBI,TH1
   TH1=TH/CA
   TH1=TH/CA
   PRINT 405, TH,TH,TH1,TH1
   SPHI=SIN(THET)
   TANG=TAN(THET)
   IF=11.1
   DBE=ABS(B1-BETA)

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2600  GO ON=ABS(ANGLE-THE1)
2601  IF (11.EQ.10) THE1=0.5*(ANGLE+THE1)
2602  IF (11.EQ.10) GO TO 28
2603  IF (DBE.GT.1.0E-7.AND.BIN.GT.1.0E-7) GO TO 1
2604  ANGLE=THE1/CA
2605  PRINT 406, ANGLE,11
2606  RETURN
2607
2608  29  H1=H2
2609  ANGLE=C/CA
2610  PRINT 406, ANGLE,11
2611  RETURN
2612
2613  30  C
2614  400  FORMAT (//, ITERATION NUMBER *,13,/)
2615  401  FORMAT (16,E16.7,BF13.8)
2616  402  FORMAT (16,F10.4,DE13.4,F10.4/)
2617  403  FORMAT (6,MIN=*,F14.6,*, BIF=*,E14.6,*, PK=*,E16.8)
2618  404  FORMAT (6, TOTAL BETA = *,E14.6,F15.6,*, FBI = *,E14.6,*, THE1 = *,F10
2619  405  4.5,*,TANG=*,F10.6)
2620  405  FORMAT (5F12.6)
2621  406  1  FORMAT (BX, /1M,*,ZENITH ANGLE =*,F7.3,*, DEGREES - RECOMPUTED
2622  406  1  FROM SUBROUTINE ANGL (ITERATION*,13,*,))
2623  END
2624  FUNCTION MUDD(I)
2625  DIMENSION MU(2)
2626  DATA MU(1),-1/
2627  J=1/2
2628  K=J-2+J+1
2629  MUDD=MU(K)
2630  RETURN
2631  2631  1

```

[illegible]